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Assessment of Alternatives for Management of ORNL Retrievable Transuranic Waste

Prepared for
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830
operated by
Union Carbide Corporation
for the
Department of Energy
Contract No. W-7405-eng-26

GAI Report 2217

Prepared by
Gilbert/Commonwealth
Reading, Pennsylvania
October 1980

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ASSESSMENT OF ALTERNATIVES FOR MANAGEMENT OF ORNL RETRIEVABLE TRANSURANIC WASTE

NUCLEAR WASTE PROGRAM

Transuranic Waste

(Activity No. AR 05 15 15 0; ONL-WT04)

PREPARED FOR

OAK RIDGE NATIONAL LABORATORY
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Date Published: February 1981

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GILBERT/COMMONWEALTH
READING, PENNSYLVANIA
OCTOBER 1980

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PREFACE

This report was prepared by Gilbert Associates, Inc., Reading, Pennsylvania under contract with ORNL Waste Management Operations. The material herein has been reviewed by ORNL Waste Management personnel, the Department of Energy's Oak Ridge Operations Office, and also by those personnel involved in similar alternative studies at Rockwell Hanford, EG&G Idaho, Los Alamos Scientific Laboratory, Savannah River Laboratory, and the TRU Waste Service Office at the Rocky Flats Plant.

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INTRODUCTION

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INTRODUCTION

The Oak Ridge National Laboratory (ORNL) generates transuranic (TRU) contaminated solid waste as a result of various processing and research programs. Prior to 1970, this waste was stored without consideration of retrievability in unlined earthen trenches and auger holes. In some cases, the waste was covered with a concrete pour prior to backfilling the trenches with soil. Since October 1970, in accordance with regulatory requirements, contaminated solid waste, exceeding 10 μCi of TRU or U-233 activity per kilogram of waste, has been stored in a retrievable fashion in a designated area of ORNL Solid Waste Storage Area No. 5. To date, four basic storage methods have been used: a) Stored Drums; b) Buried Concrete Casks; c) Stored Concrete Casks; and d) Stainless Steel Lined Wells.

The original intent of the retrievable storage concept was to provide a safe, retrievable storage method for an interim period of time (approximately 20 years), while ultimate disposal methods via a Federal TRU waste repository were being identified and developed. The outlook for the availability of the Federal repository by the end of the original 20-year storage period is uncertain at this time. This has prompted the Department of Energy (DOE) to initiate alternative TRU waste management studies at ORNL and other locations where TRU waste has been stored. This report summarizes the result of such a study for ORNL. Similar studies for the Savannah River Plant (SRP) and the Idaho National Engineering Laboratory (INEL) have already been published (USDOE 1979 a,b).

The objectives of this report are to review current TRU waste storage practices and to assess alternatives for the long-term management of ORNL's retrievable TRU waste. Management of ORNL's non-retrievable TRU waste is not considered herein; non-retrievable TRU waste will be addressed separately in later phases of this effort.

The following factors have affected the conduct of the study:

A. Regulations and specifications being formulated by Federal agencies concerning the disposal of TRU wastes, i.e., repository licensing, repository waste acceptance criteria, etc., are not well defined, at present. These considerations will have a significant impact on the conclusions of this study and in any future decision to implement a particular alternative.

B. The evaluations performed on alternatives involving processing the waste are limited, to a large extent, by the degree of detail available on physical and chemical composition, material form and isotopic breakdown of the waste contaminants. Likewise, the evaluation of alternatives involving in-situ disposal are limited by the lack of detailed information on the in-situ conditions.

C. Budget and schedule limitations for the study made it necessary to limit the number of the alternatives considered to only those options which are expected to be the most suitable for ORNL's retrievable TRU wastes and the detail of the evaluations performed to that appropriate for a feasibility evaluation.

In order to accommodate these factors and provide a meaningful evaluation of alternatives for the management of ORNL's retrievable TRU waste, the following scope items were adopted:

A. The strategies to be considered in developing alternatives are:

- Strategy 1: Leave waste in place as is
- Strategy 2: Improve waste confinement
- Strategy 3: Retrieve waste and process for shipment to a Federal repository

Additional strategies such as exhuming the waste and preparing it for shipment to a central processing facility or for disposal at a location other than a Federal repository, etc. are beyond the scope of the present study.

B. The TRU waste stored through 1995 is to be considered in identifying and evaluating alternatives. The waste storage methods are assumed to be those in current use. The projected storage rate is assumed to be the same as the average rate for the period from the beginning of storage to January 1980.

C. All alternatives are evaluated on the basis that they would be implemented beginning in 1995.

D. For Strategy 3, the Federal repository is assumed to be available in 1995. For evaluation purposes, the repository is assumed to be 2,500 miles from ORNL. Costs, risks and impacts after the arrival of the waste at the repository are outside the scope of this study.

E. Conceptual designs shall be developed as part of the study for any improvements or new facilities required for the alternatives evaluated.

F. For any alternative that relies on institutional control for waste isolation, such control is assumed to continue for no more than 100 years past the 1995 implementation date. During the control period, continued operation of ORNL in a manner similar to present practice is assumed.

G. The evaluation of alternatives should address licensing and regulatory requirements, technical and economic feasibility, radiation exposure, environmental impact, risks, benefits and operation and decommissioning of facilities.

H. Waste processing alternatives should, to the extent practicable, utilize existing technology and reasonably well developed processes and equipment.

I. Processing alternatives are not to be limited by repository waste acceptance criteria, since no definite requirements are identified at this time. However, at the direction of the TRU Program Office, waste immobilization matrices are limited to glass and basalt.

SECTION 2.0

SUMMARY AND CONCLUSIONS

SECTION 2.0

SUMMARY AND CONCLUSIONS

Since 1970, solid waste with TRU or U-233 contamination in excess of 10 μCi per kilogram of waste has been stored in a retrievable fashion at ORNL. The following storage methods have been used:

- Stainless steel drums in an 85 percent below grade facility.
- Concrete casks buried in earthen trenches, backfilled with native soil (discontinued in 1979).
- Concrete casks stored in a cave-like facility built into the side of a knoll (initiated in 1980).
- Waste packages of varying dimensions stored in stainless steel lined wells.

This report describes the results of a study performed to identify and evaluate alternatives for management of this waste and of the additional waste projected to be stored through 1995.

The study was limited to consideration of the following basic strategies:

- Strategy 1: Leave waste in place as is
- Strategy 2: Improve waste confinement
- Strategy 3: Retrieve waste and process for shipment to a Federal repository

Seven alternatives were identified and evaluated, one each for Strategies 1 and 2 and five for Strategy 3, as follows:

Alternative 1: Continue monitoring, maintenance and security similar to present practices. At the end of 100 years, institutional control is assumed to end. The waste would then be left unattended.

Alternative 2: Improve the confinement of the waste by: a) retrieving the buried casks and placing them in a structure above the water table similar to that being used for the stored casks; b) installing clay linings beneath and around each layer of waste containers; c) constructing a clay cap and rip rap cover over each waste storage location; d) constructing a gravity underdrain system around each waste storage location; and e) emplacing additional monitoring wells and soil lysimeters at selected locations. Monitoring, maintenance and security would continue during an assumed institutional control period of 100 years. The waste would then be left unattended with only the passive measures listed above to assure waste isolation.

Alternative 3A: Retrieve the waste containers and overpack the drums and concrete casks as they are retrieved. Overpack the waste packages from the lined wells in an existing facility at ORNL. Ship the overpacked waste containers to a Federal repository.

Alternative 3B: This alternative is the same as 3A except that the waste stored in the concrete casks would be size reduced as necessary and repackaged in drums in a facility that would be built near the waste storage area.

Alternative 3C: Retrieve the waste containers. Size reduce and compact the waste stored in drums and concrete casks. Overpack the waste packages from the lined wells in an existing facility at ORNL. Ship the processed waste to a Federal repository.

Alternative 3D: This alternative is the same as 3C except that the waste stored in drums and concrete casks would be incinerated in a molten glass incineration facility that would be built near the waste storage area.

Alternative 3E: This alternative is the same as 3C except that the waste stored in drums and concrete casks would be incinerated in a rotary kiln facility that would be built near the waste storage area. The incineration residue would be immobilized in a basalt-like slag.

Each of the alternatives listed above was evaluated from the standpoint of technical feasibility, cost, radiological risk and impact, regulatory factors and non-radiological environmental impact. Table 2-1 is a compilation of these evaluation factors for each alternative. The following conclusions were reached as a result of the evaluations:

A. Alternative 1 should not receive continued consideration as a long term (>100 years) waste management option because of its high risk, likelihood of regulatory disapproval and possibility of substantially higher cost than that indicated in Table 2-1 as the storage containers deteriorate over time. However, these considerations do not prevent continued use of this alternative as an interim (~20 years) storage method.

B. Preliminary investigation of the geohydrological characteristics of the retrievable waste storage area and the long term integrity of the improved confinement measures should be initiated in order to better assess the ability of Alternative 2 to isolate the waste during the period that it is hazardous. Unless these investigations or other factors not considered in the present investigation preclude this alternative, it should receive continued consideration as a waste management option for ORNL's retrievable waste.

C. Alternative 3A appears to be the best option. It is comparatively low in cost and has relatively few disadvantages. However, a major difficulty in implementing this alternative could occur if the waste acceptance criteria for the Federal repository does not allow the waste in its present form. Even if this should occur, Alternative 3A represents a viable option as part of a waste management strategy involving shipment of the waste to a central waste processing facility.

D. Alternatives 3B and 3C not do not offer any significant advantages with respect to Alternative 3A and are significantly more costly.

E. The primary advantages of Alternatives 3D and 3E with respect to the other Strategy 3 alternatives is that they would be expected to encounter the least difficulty in meeting waste acceptance criteria that could be adopted for the Federal repository. The cost of these alternatives are significantly higher than all the other alternatives considered. It should be noted that the incineration processes for Alternatives 3D and 3E were selected on the basis of a qualitative review for the purpose of considering incineration in the present evaluation. If incineration of ORNL's TRU waste is selected for further study, it is recommended that a detailed engineering evaluation be performed to definitively determine which incineration process is the most suitable. If considered necessary after this evaluation, pilot plant tests should be performed to demonstrate the feasibility of the process and any required immobilization.

TABLE 2-1 COMPILATION OF EVALUATION FACTORS

Alternative	Description	Total Estimated Cost (Millions of 1980$)	Radiological Risk (Estimated Cancer Fatalities)	Regulatory Difficulties	Non-Radiological Environmental Impact	Development Needs
1	Leave waste as is. Continue monitoring, maintenance and security	$ 3.4	2.9E + 02[a] + intrusion	high	minimal	minimal
2	Improve confinement of waste. Continue monitoring, maintenance and security	11.2	1.3E - 01 + intrusion	(b)	minimal	medium
3A	Overpack drums and casks as retrieved. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	10.9	6.0E - 02	low[c]	minimal	low
3B	Overpack drums as retrieved. Size reduce and repackage wastes from concrete casks in a repackaging facility. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	39.1	6.8E - 02	low[c]	minimal	low
3C	Size reduce and compact waste from drums and casks in a compaction facility. Overpack waste packages from lined wells in Building 3525. Ship waste to Federal repository	38.7	7.0E - 02	low[c]	minimal	low

TABLE 2-1 COMPILATION OF EVALUATION FACTORS

Alternative	Description	Total Estimated Cost (Millions of 1980$)	Radiological Risk (Estimated Cancer Fatalities)	Regulatory Difficulties	Non-Radiological Environmental Impact	Development Needs
3D	Incinerate waste from casks and drums in a molten glass incinerator. Size reduce and repackage bulk metal items. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	$55.0	7.4E - 02	low[c]	minimal	high
3E	Incinerate waste from casks and drums in a rotary kiln. Size reduce bulk metal items. Immobilize size reduced metal and incinerator residue using a basaltic slag. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	56.7	7.4E - 02	low[c]	minimal	high

Notes:

a. 2.9E + 02 same as 2.9×10^2

b. Dependent on detailed evaluation of geohydrological characteristics of waste storage area and investigation of long term integrity of improved confinement measures.

c. Assumes that waste acceptance criteria are not sufficiently different from those described in Appendix B (in this report) to preclude the alternative.

SECTION 3.0

DESCRIPTION OF ORNL TRANSURANIC SOLID WASTES AND STORAGE

SECTION 3.0

DESCRIPTION OF ORNL TRANSURANIC SOLID WASTES AND STORAGE

3.1 WASTE GENERATION

TRU contaminated solid waste at ORNL consists of material contaminated b plutonium and heavier elements such as curium, californium and americium Waste material contaminated with the nuclide U-233 is also included in t category although U-233 is not a TRU nuclide.

The facilities at ORNL that generate most of the TRU solid waste are:

Building	Facility
3019	Radiochemical Processing Pilot Plant
3028	Radioisotopes Production Laboratory A
3508	Chemical Technology Alpha Laboratory
5505	Transuranium Research Laboratory
7900	High Flux Isotopes Reactor
7920	Transuranium Processing Plant
7930	Thorium - Uranium Recycle Facility

3.2 WASTE STORAGE

Prior to 1970, TRU solid waste at ORNL was stored non-retrievably in unli earthen trenches and auger holes. Since October 1970, contaminated solid waste, exceeding 10 μCi of TRU or U-233 activity per kilogram of waste, h been stored in a retrievable fashion in a designated (fenced-off) area of Solid Waste Storage Area No. 5. An aerial view of the TRU waste storage is shown in Figure 3-1.

Four retrievable storage schemes have been used to date: a) Stored Drums; b) Buried Concrete Casks; c) Stored Concrete Casks; and d) Stainless Steel Lined Wells. Each of these storage schemes is discussed below.

Drums: TRU contaminated solid waste that is not expected to exceed a surface dose rate of 200 mrad/hr is packaged in 0.114 or 0.208 cubic meter (30 to 55 gallon) stainless steel drums. The 0.208 cubic meter drum is the most commonly used size. The drums are sealed with a neoprene gasket and a bolted closure ring as shown in Figure 3-2. The drums are held temporarily in a staging area, Building 7823, until a sufficient number has accumulated for transfer to the Retrievable Drum Storage Facilities, Buildings 7826 and 7834 (see Figure 3-1). These concrete block buildings are 85 percent below grade with 24 cells in which drums are stacked in layers. Plan and section views of Building 7826 are shown in Figures 3-3 and 3-4, respectively. The design of Building 7834 is similar except that the cells are somewhat deeper (and can thus accommodate an additional layer of drums) and are covered with removable concrete plugs instead of metal roofing. Total storage capacity is 1,536 and 1,920 drums (0.208 cubic meter) for Buildings 7826 and 7834, respectively.

At the end of 1979, there were approximately 1,600 drums stored in these buildings. Approximately 1,300 of these are stainless steel drums; the remainder are black iron drums. The black iron drums were generated during the initial stages of retrievable storage; the use of these drums was discontinued due to deterioration. These drums are periodically inspected and maintained.

Concrete Casks: TRU contaminated solid waste, which exceeds 200 mrad/hr or is accompanied by high levels of neutron emission and generated in relatively high volumes, is placed in reinforced concrete casks. These casks have wall thicknesses of either 0.114, 0.152, or 0.305 meters (4.5, 6, or 12 inches) and are approximately 1.27 to 1.37 meters (50 to 54 inches) in diameter and 2.13 to 2.44 meters (7 to 8 feet) in height. Engineering drawings of these concrete casks are shown in Figures 3-5, 3-6 and 3-7. The use of the 0.114 meter casks has been discontinued.

Up through 1979, the concrete casks were placed in unlined earthen trenches (Figure 3-8) and backfilled with native soil. This practice ended in 1979 and casks generated since that time are placed in a cave-like structure built into the side of a knoll (Building 7855, see Figure 3-1). The building is designed to allow forklift access for placing the casks in storage as shown in Figure 3-9.

At the end of 1979, there were approximately 190 casks stored in earthen trenches. Storage of casks in Building 7855 did not begin until 1980.

Stainless Steel Lined Wells: High radiation level, beta-gamma TRU waste which is generated in relatively low volumes is packaged on a case-by-case basis. The containers are of various sizes. These waste containers are stored in stainless steel lined wells (Buildings 7827 and 7829). The diameter and depth of the wells are variable; details of a portion of Building 7827 are shown in Figure 3-10. Waste containers are lowered by cable into the well from a shielded carrier and the well is closed with a stepped concrete plug. The lifting cable is stored with the container to aid in retrievability.

3.3 WASTE INVENTORY

Data on the volume and isotopic activity of TRU waste placed in retrievable storage are maintained in computer files developed to produce reports for the Solid Waste Inventory Management System (SWIMS). Data from these files were used to determine the quantity and activity of the waste stored retrievably through the end of 1979 and to project these inventories to 1995.

The volume projections were made assuming that the storage rate in the future would be equivalent to the average rate through 1979. The isotopic activity projections were performed using the average activity storage rate through 1979 adjusted for decay during the storage periods. Activity projections were performed only for those isotopes that are present in large enough quantities to be of significance in the dose and risk assessment calculations presented in Section 7.0. The current and projected volumes and activities of retrievable TRU wastes are presented in Tables 3-1 and 3-2, respectively.

It should be noted that the projected values presented in Tables 3-1 and 3-2 do not reflect TRU wastes quantities that would be generated as a result of future Decontamination and Decommissioning (D&D) activities at ORNL. The effect of planned D&D efforts (to 1995) on the TRU waste inventory is discussed in Section 10.0, Appendix D.

3.4 WASTE CHARACTERISTICS

Information on the physical and chemical characteristics of the waste was obtained by reviewing the operations and records of the Radiochemical Processing Pilot Plant (Building 3019), the Transuranium Processing Plant (Building 7920) and the High Radiation Level Examination Laboratory (Building 3525). The waste from these buildings is typical of the waste stored in drums, concrete casks and waste packages in the lined wells, respectively. The information on waste characteristics presented in subsequent subsections is provided to show the general characteristics of the waste included in each storage scheme. More detailed definition of the waste properties is recommended prior to implementing any waste management option involving processing.

3.4.1 Drums

The waste generated in Building 3019 is typical of the waste stored in drums. Waste in this building is placed in stainless steel drums as it is generated. Routine practice is to segregate combustibles and noncombustible waste into separate drums to the extent practicable. However, in reviewing Building 3019 records, it is apparent that large noncombustible items (pumps, scales, tools, tubing, etc.) occasionally have been mixed in with the combustible waste.

The constituents of the waste from Building 3019 are typical of a glove-box radiochemical processing operation and include the following:

- cheesecloth
- cotton swabs
- crushed tin cans
- failed processing equipment (pumps, etc.)
- glove-box filters
- glove-box gloves
- granulator screens
- hand tools
- household plastic gloves
- plastic bottles
- plastic for bag out
- silica gel
- rags
- vacuum cleaner bags
- wipes

3.4.2 Concrete Casks

Most of the wastes stored in concrete casks is generated in Building 7920. Therefore, the operations conducted and waste material generated in this building provide a general indication of the physical nature of the waste to be typically found in the concrete casks, as described below.

The design of Building 7920 is such that only one concrete cask at a time can be used for waste collection. Consequently, segregation of the waste into combustible and noncombustible portions is only done on a limited basis.

Most of the waste consists of small items from hot cell operation which are placed in 3.8 liter (one gallon) metal cans similar to paint cans. After each can is full, it is sealed with a metal lid. The entire can is then heat sealed in a polyethylene overpack. The polyethylene overpacks are placed in a concrete cask. Wastes packaged in this manner include:

- bags
- cut up manipulator boots
- glassware
- O-rings
- plastic tubing
- polyethylene bottles
- polyethylene equipment blocks
- rubber stoppers
- small tools
- wipes

In addition to these items, a limited number of casks (approximately 20, through 1979) also contain large metal items such as equipment racks, pumps, furnaces, etc.

3.4.3 Lined Wells

The waste generated in Building 3525 is typical of the waste stored in the lined wells and consists mostly of fuel elements and similar material that is cut up for examination as part of ORNL's nuclear fuels program. The waste is packaged on a case-by-case basis in the hot cells in Building 3525 and transported to the retrievable storage area in shielded carriers.

TABLE 3-1 CURRENT AND PROJECTED VOLUMES OF RETRIEVABLE TRU WASTE

Storage Type	Volume of Waste Stored Through 1979 as Reported in SWIMS		Adjusted Volume of Waste Stored Through 1979		Projected Volume of Stored Waste in 1995[a]	
	Combustible (m^3)	Noncombustible (m^3)	Combustible (m^3)	Noncombustible (m^3)	Combustible (m^3)	Noncombustible (m^3)
Drums	192	158	192	158	480	400
Buried Casks	208	322	115[b]	177[b]	115	177
Stored Casks	0	0	0	0	170	270
Lined Wells	0.3	2.6	0.3	2.6	0.1	6.5

Notes:

a. Projections are based on adjusted volumes.

b. Volume data listed in SWIMS files is total of physical volume of waste plus volume of container material. Breakdown of this total into combustible and noncombustible fractions in computer files does not reflect noncombustible nature of storage containers. Prior to projecting data for concrete casks, concrete volume was subtracted from totals. This volume number was adjusted using combustible/noncombustible fractions determined from computer files.

TABLE 3-2 CURRENT AND PROJECTED ACTIVITY OF DOSE SIGNIFICANT ISOTOPES IN RETRIEVABLE TRU WASTE

Storage Type	Isotope	Activity Stored Through 1979 (Ci)	Projected Activity Stored in 1995 (Ci)
Drums	Am-241	1.137E + 04[a]	2.8E + 04
	Cf-252	2.800E + 05	1.1E + 05
	Cm-244	2.117E + 05	3.4E + 05
	Pu-238	7.766E + 03	1.8E + 04
	Pu-239	1.508E + 02	3.8E + 02
	Pu-240	1.153E + 02	8.0E + 02
Buried Casks	Cf-252	6.672E + 04	1.3E + 03
	Cm-244	1.279E + 05	5.9E + 04
	Pu-239	1.230E + 01	1.2E + 01
	Pu-240	-	1.8E + 02
Stored Casks	Cf-252	-	2.5E + 04
	Cm-244	-	1.4E + 05
	Pu-239	-	1.9E + 01
	Pu-240	-	1.4E + 02
Lined Wells	Cm-244	5.08E + 02	8.1E + 02
	Pu-239	2.20E + 01	5.5E + 01
	Pu-240	-	1.2

Note:

a. 1.137E + 04 same as 1.137×10^4

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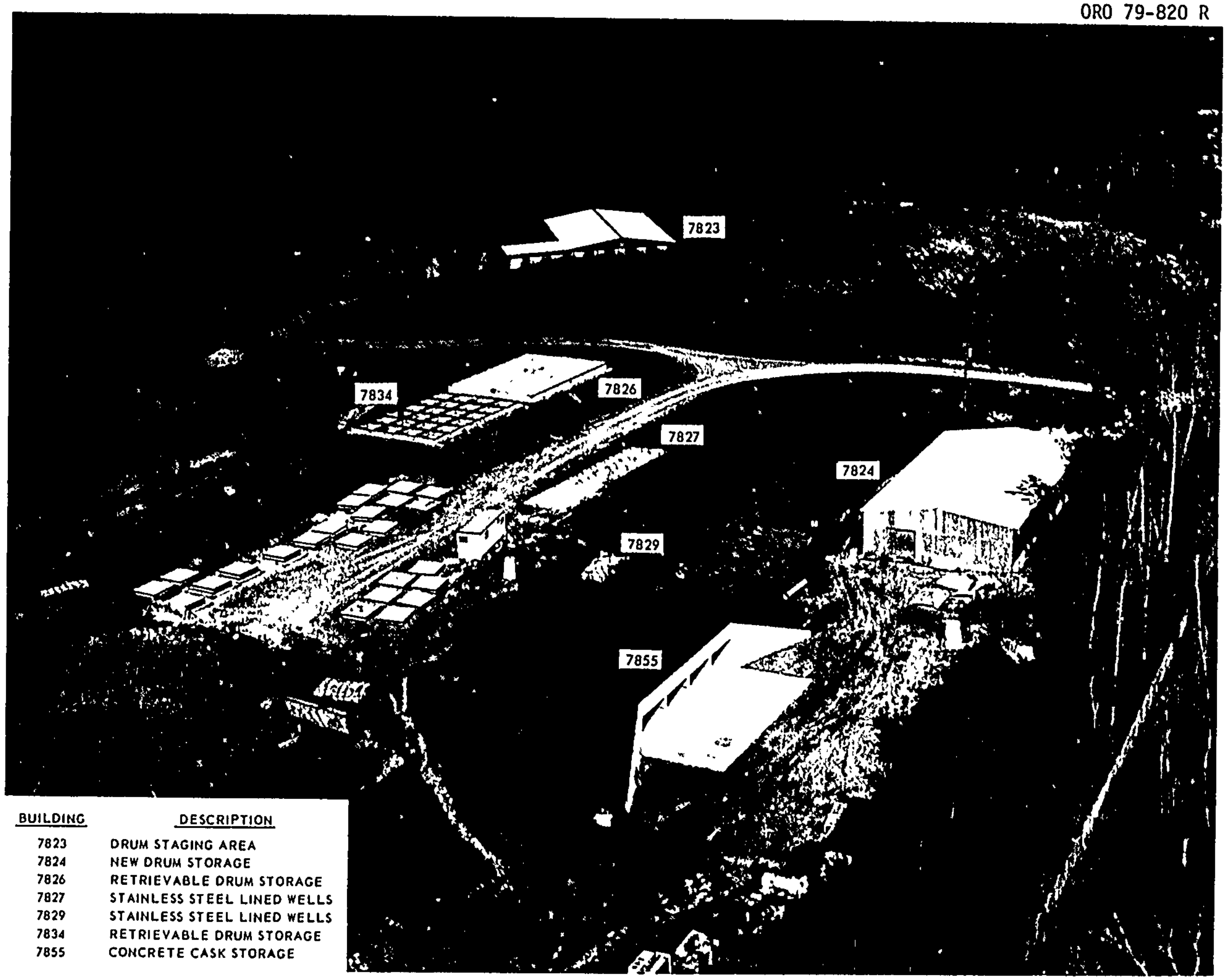


FIGURE 3-1 AERIAL VIEW OF TRU WASTE STORAGE AREA

ORNL PHOTO 0223-74 R

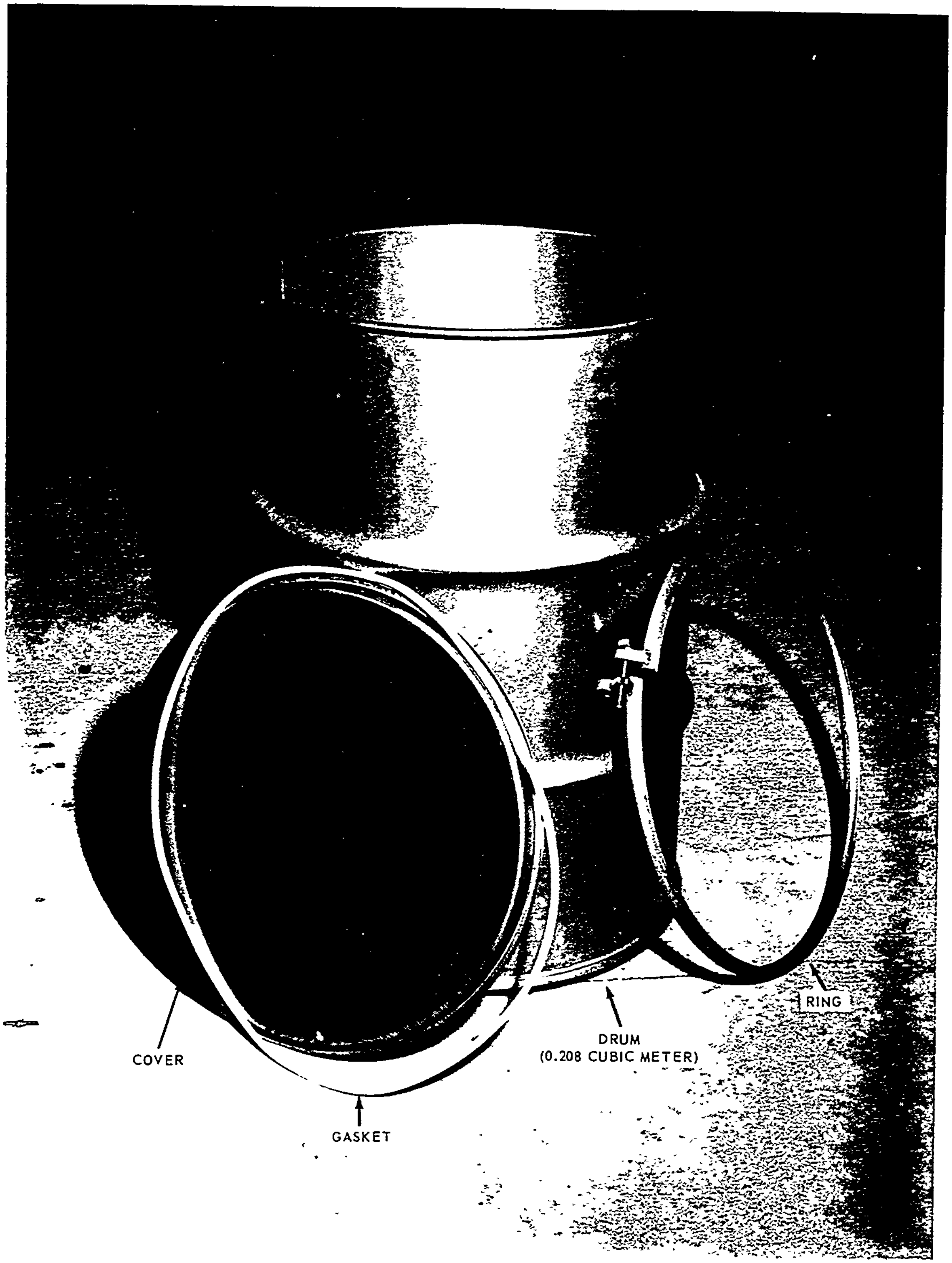


FIGURE 3-2 TYPICAL STAINLESS STEEL DRUM

ORNL DWG 81-4916

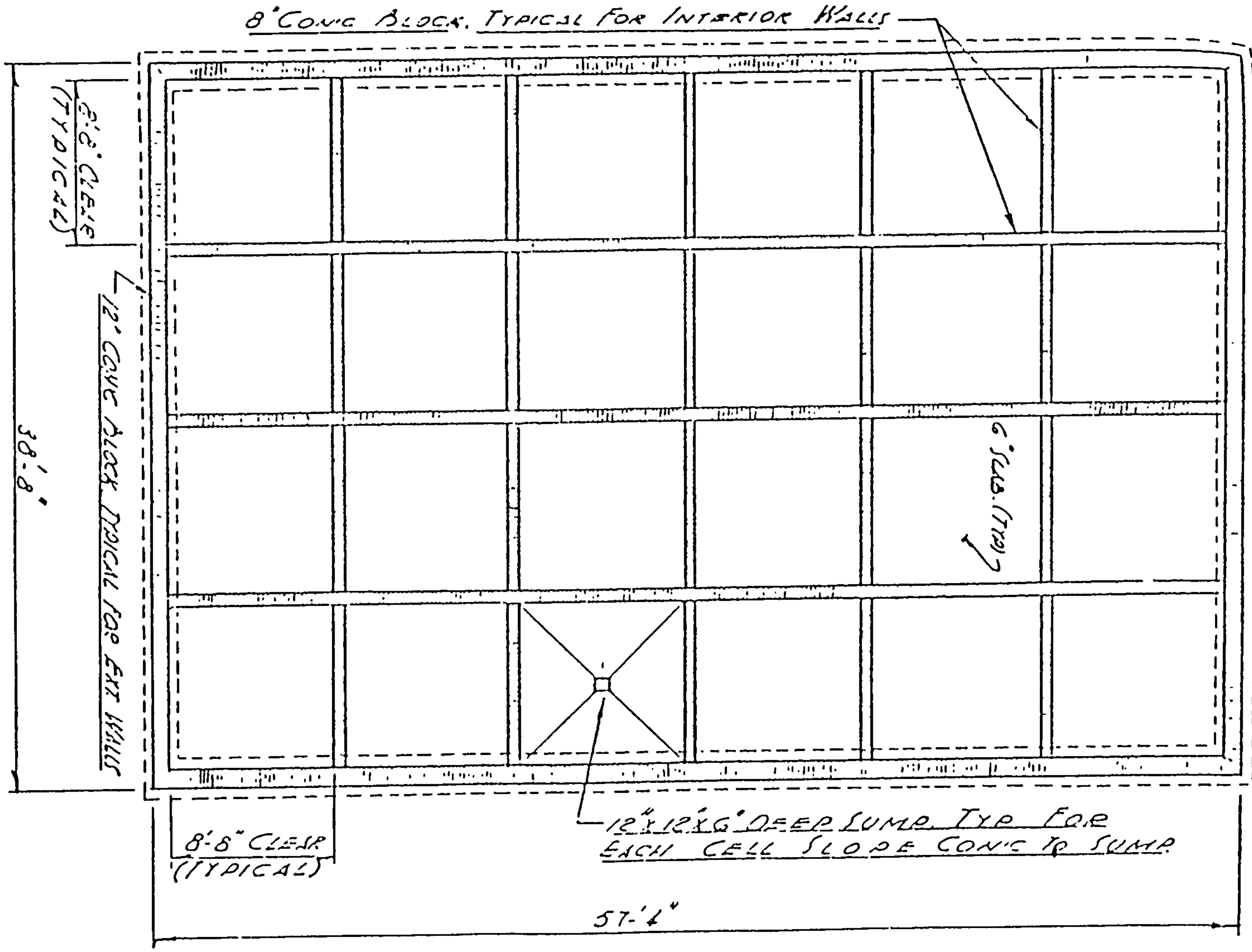


FIGURE 3-3 STORAGE FACILITY FLOOR PLAN FOR RETRIEVABLE WASTE PACKAGED IN DRUMS

ORNL DWG 81-4917

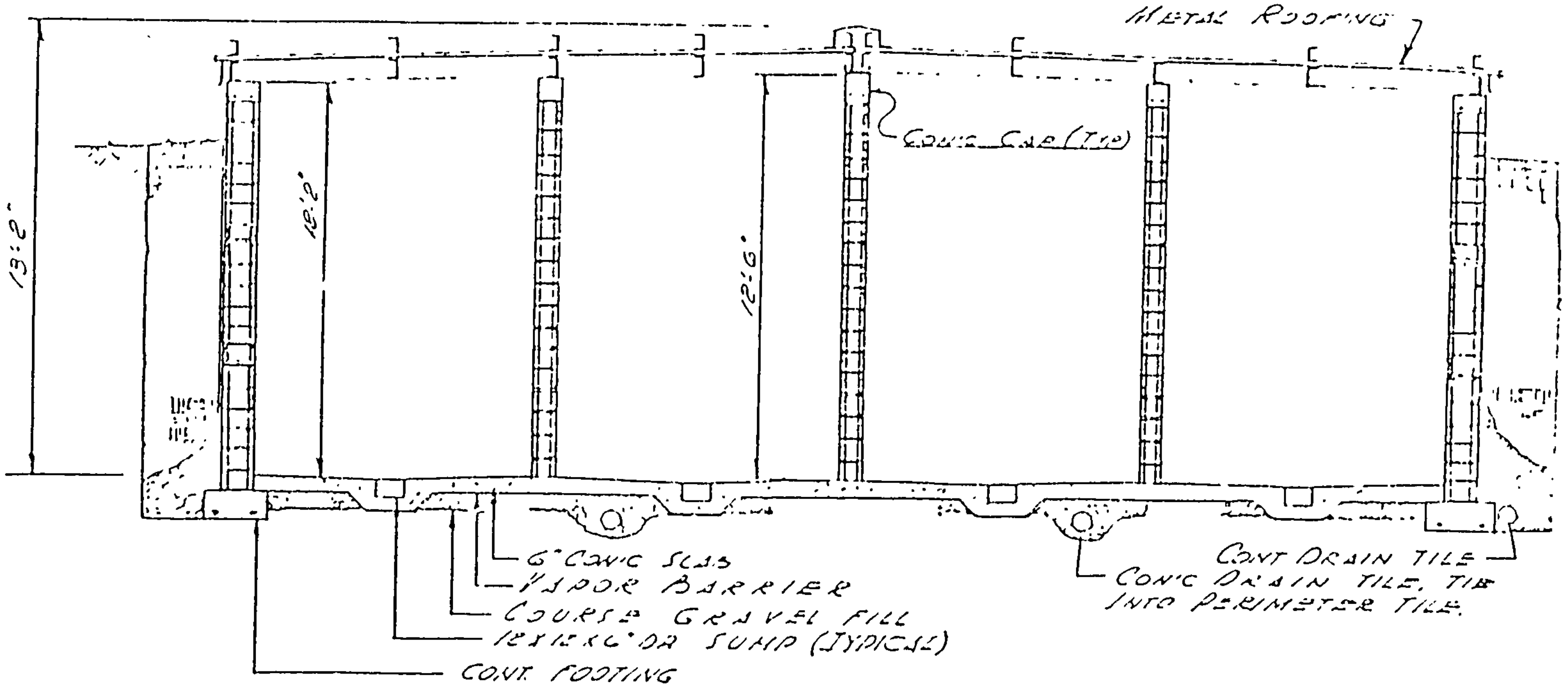


FIGURE 3-4 STORAGE FACILITY CROSS SECTION FOR RETRIEVABLE WASTE PACKAGED IN DRUMS

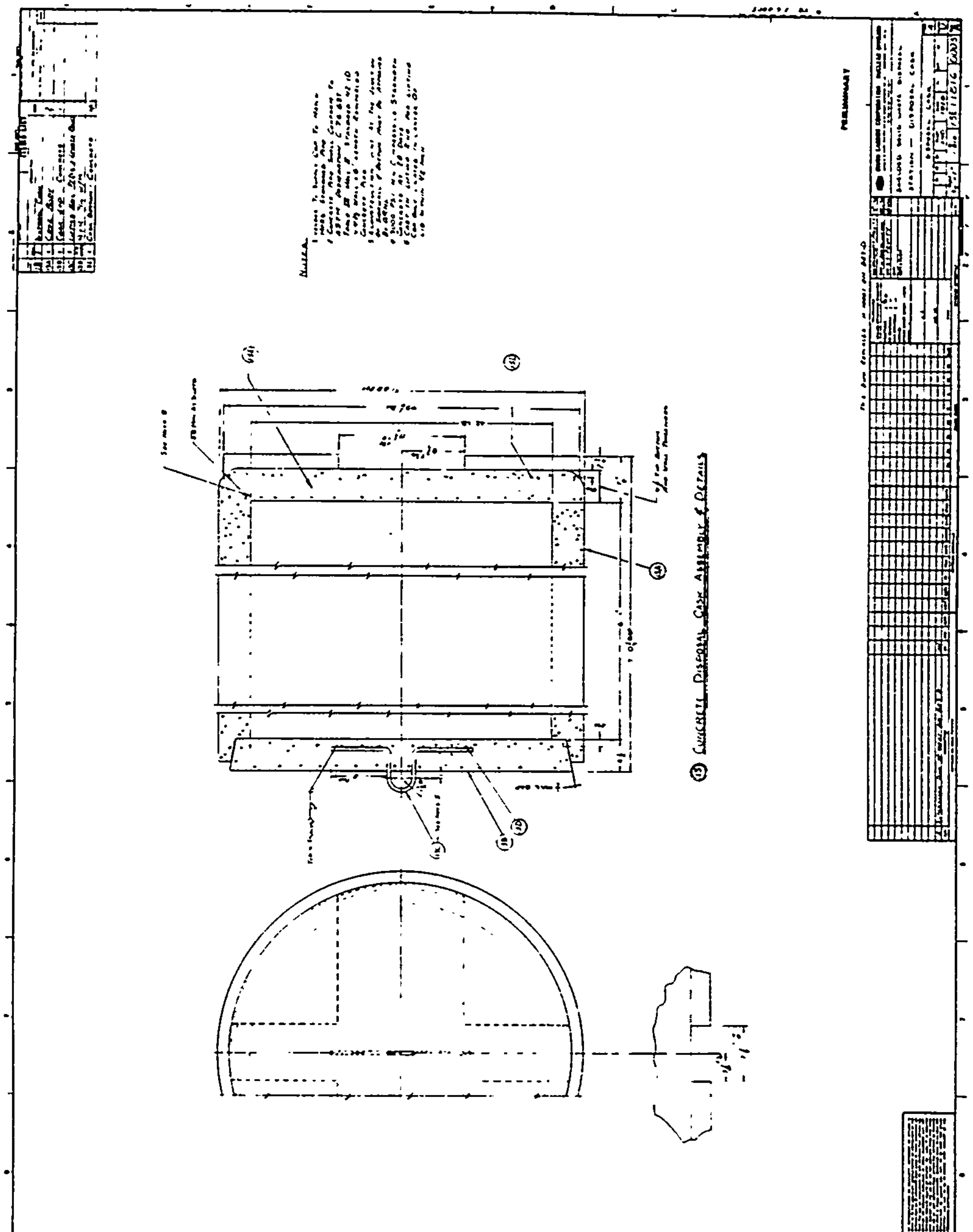


FIGURE 3-5 DETAILS OF CONCRETE CASK 0.114 METER THICK

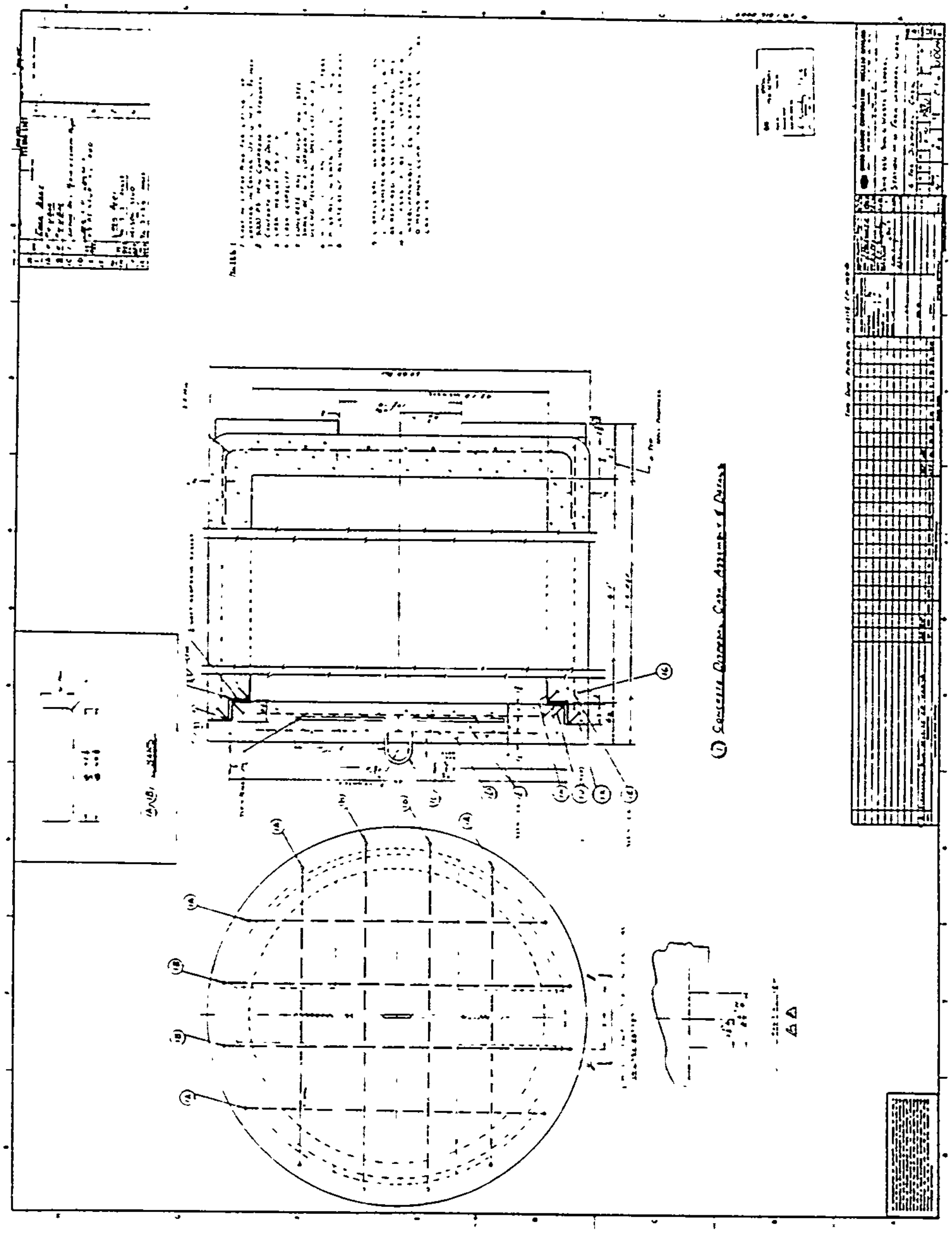


FIGURE 3-6 DETAILS OF CONCRETE CASK 0.152 METER THICK

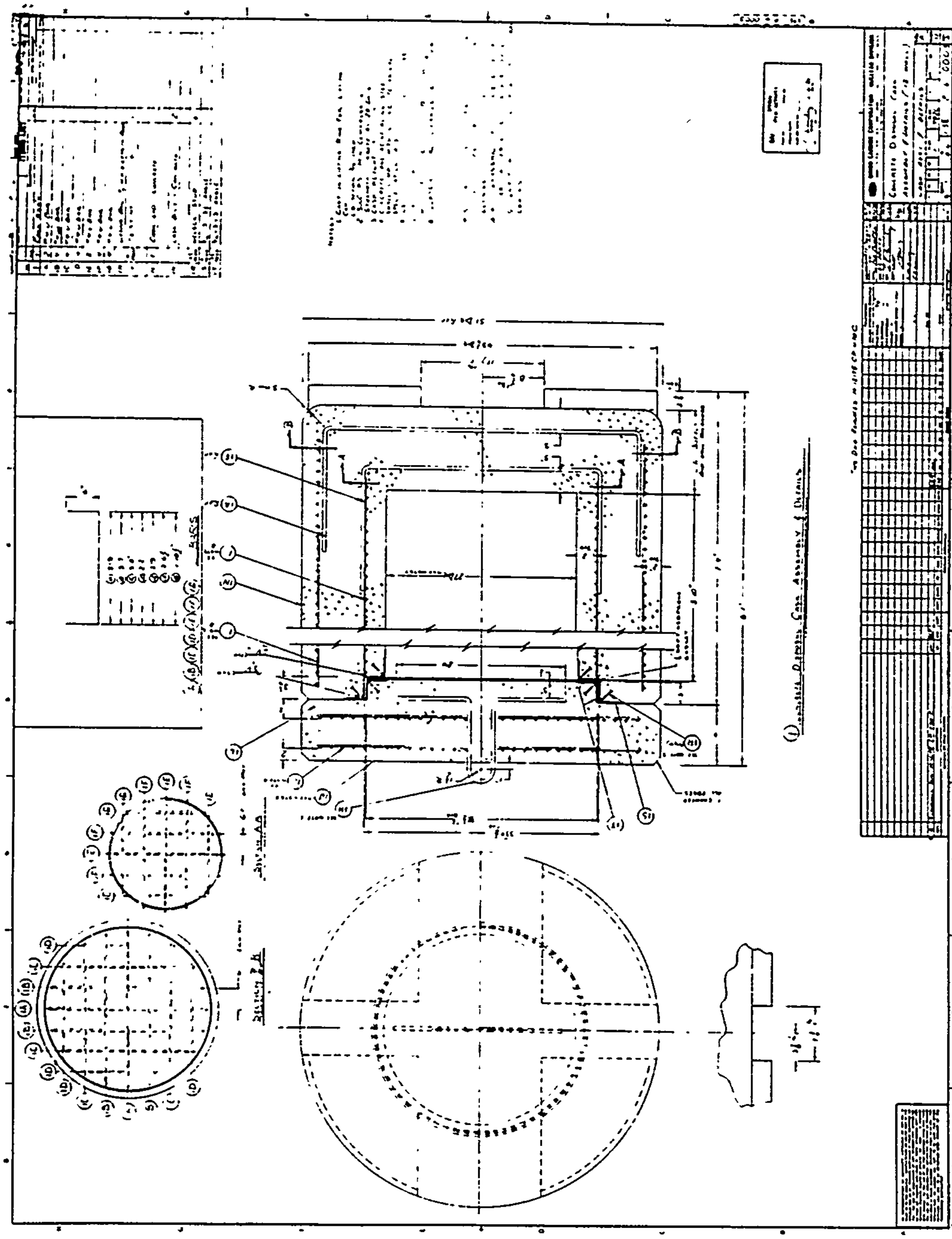


FIGURE 3-7 DETAILS OF CONCRETE CASK 0.305 METER THICK

ORNL PHOTO 1647-71

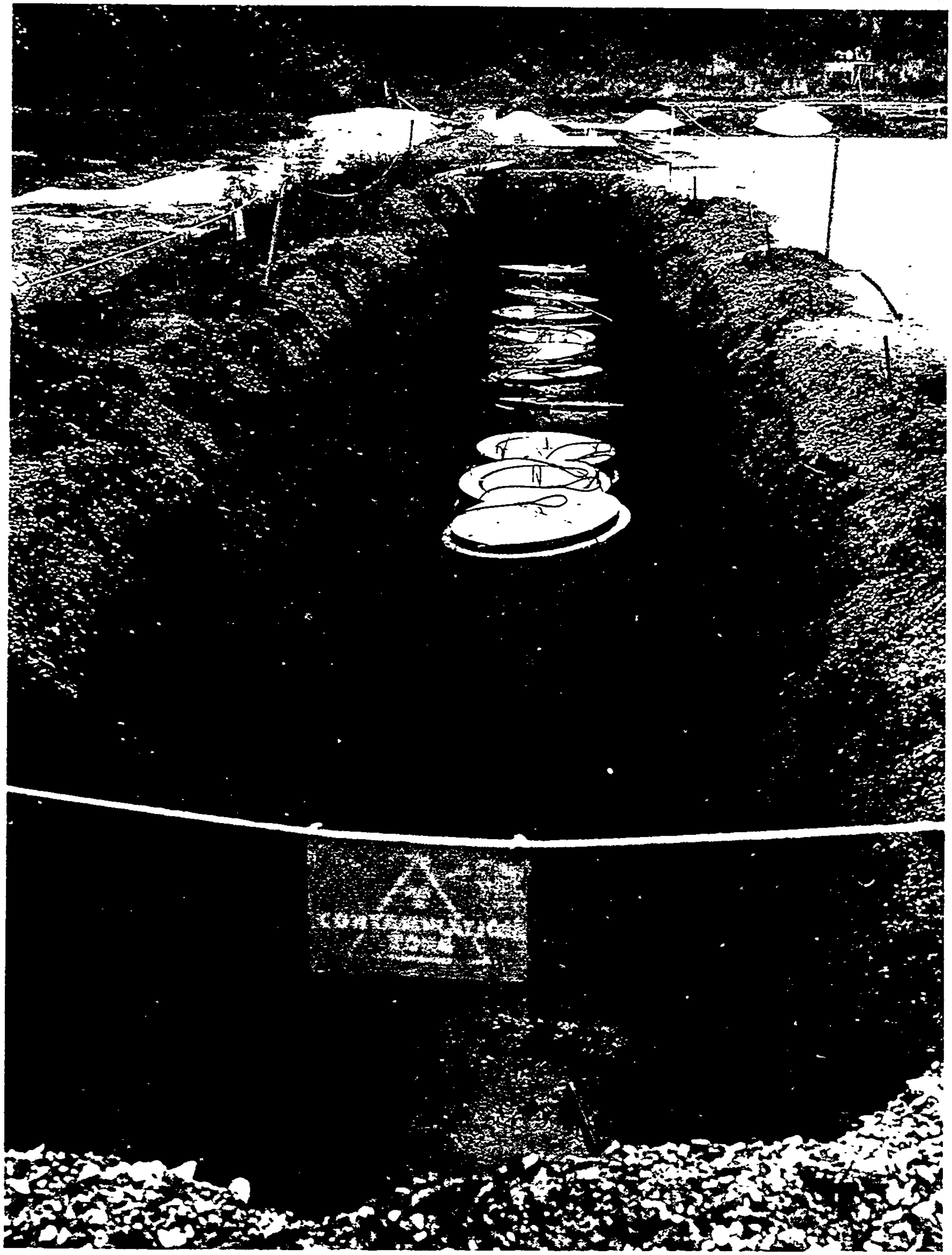


FIGURE 3-8 TRENCH WITH CONCRETE CASKS CONTAINING BETA-GAMA TRU WASTE

ORNL PHOTO 3465-80

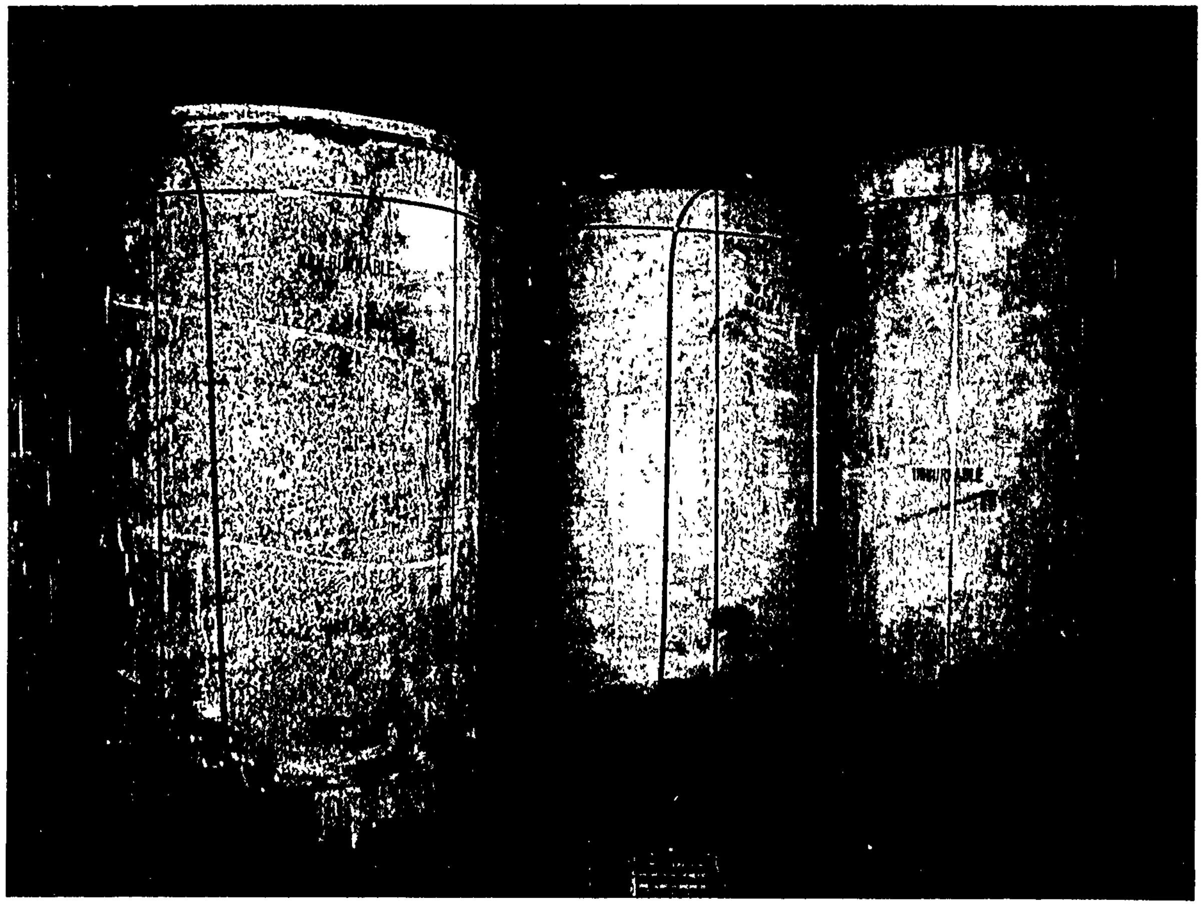


FIGURE 3-9 STORAGE BUILDING 7855 WITH CONCRETE CASKS CONTAINING BETA-GAMMA TRU WASTE

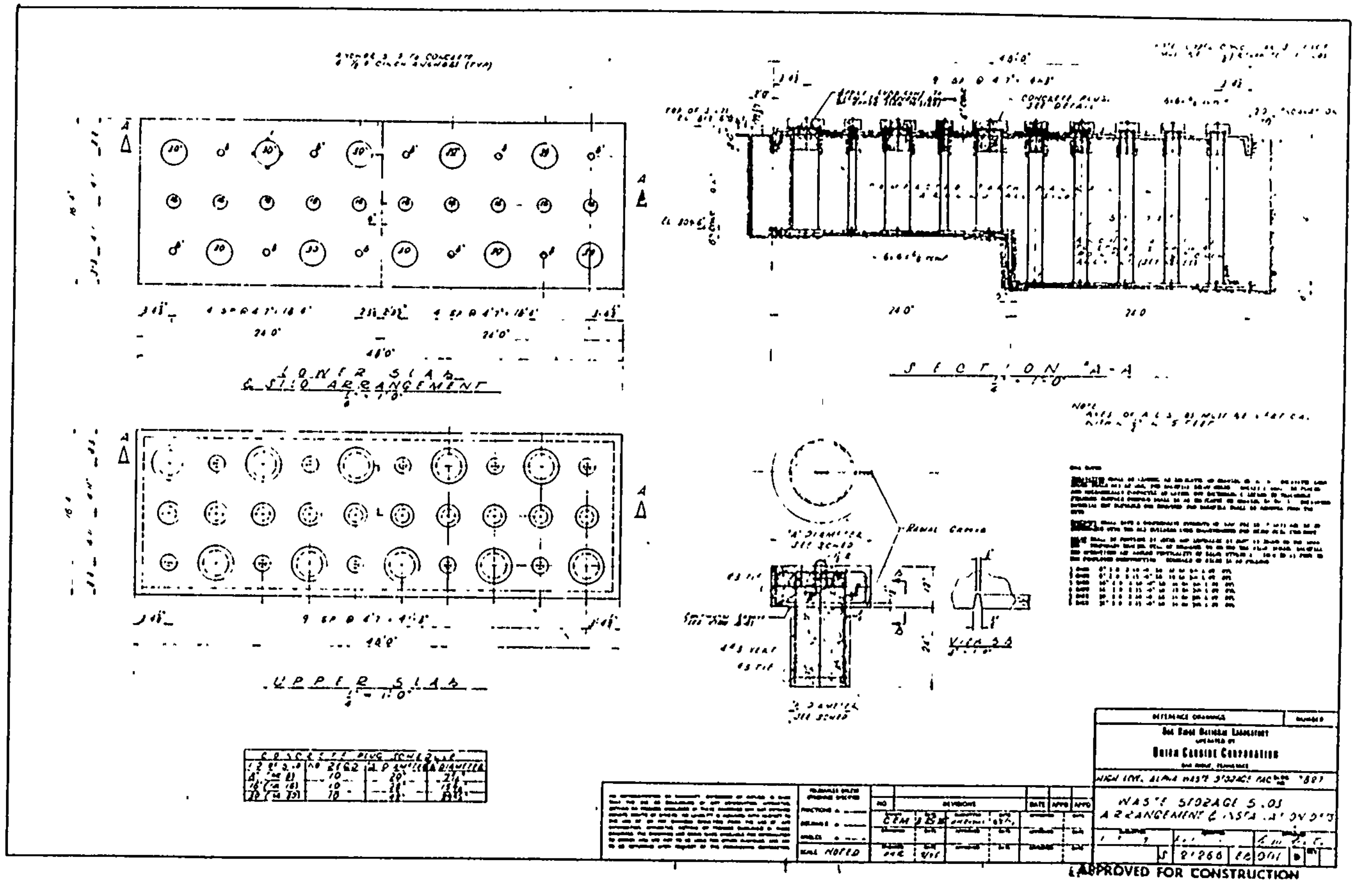


FIGURE 3-10 DETAILS OF STAINLESS STEEL LINED WELLS

SECTION 4.0

IDENTIFICATION OF RETRIEVABLE TRU WASTE MANAGEMENT ALTERNATIVES

SECTION 4.0

IDENTIFICATION OF RETRIEVABLE TRU WASTE MANAGEMENT ALTERNATIVES

Alternatives for the management of ORNL's retrievable TRU waste were identified for each of the following strategies (see Section 1.0):

- Strategy 1: Leave waste in place as is
- Strategy 2: Improve waste confinement
- Strategy 3: Retrieve waste and process for shipment to a Federal repository

The alternatives considered for each strategy are discussed in the following subsections. The alternatives that appear to best accomplish each strategy were selected for additional evaluation.

4.1 STRATEGY 1: LEAVE WASTE IN PLACE AS IS

This strategy is the base case against which the other options are assessed. It is similar to present practices. The specific elements of this alternative are:

- Continue monitoring, maintenance and security for an assumed institutional control period of 100 years.
- At the end of the institutional control period, the waste storage area is left as is, unattended.

During the control period, monitoring, maintenance and security would consist of: a) checking sumps and monitoring wells for the presence of water and analyzing any water present for radioactivity; b) taking air samples from the storage buildings; c) visual inspection of the containers and buildings; d) repairs to the storage buildings, waste containers and security fencing; mowing of grass, filling any subsided or eroded areas and periodic painting of the iron drums; and e) periodic patrols of the waste storage area and response to any reported entrance of unauthorized personnel.

4.2 STRATEGY 2: IMPROVE WASTE CONFINEMENT

Improvement in TRU waste confinement could be accomplished by implementing any one or a combination of the following actions:

A. Construction of a clay liner inside each storage building and between each layer of waste.

B. Construction of a clay cap and rip rap cover over each waste storage location.

C. Construction of a gravity underdrain system around each waste storage location.

D. Retrieval of the buried casks and placement in a storage location similar to Building 7855.

E. In place encapsulation of the waste using pressure grouting techniques.

F. Construction of grout curtains around and under the storage areas.

G. Retrieval of all waste and placement in a massive engineered structure designed to endure for the period that the waste is hazardous.

For most of the above actions, it would also be desirable to implement the following measures: the addition of soil lysimeters at selected locations to provide a means of sampling the soil moisture around the waste storage locations; and the use of additional monitoring wells to provide both information on groundwater levels at the TRU waste storage area and an improved means of detecting migration of leakage from the waste containers, if it occurs.

The optimum combination of actions considered to be representative of Strategy 2 and selected for assessment in this study is a combination of items A through D in conjunction with the additional monitoring measures discussed above. Items A through D were selected because they reduce the possibility of water percolating or infiltrating into the waste. If any water was able to penetrate the proposed barriers, the migration of any resultant leachate would be significantly retarded. The clay liners and caps proposed have a plastic, self-healing ability and would be expected to retain their integrity significantly beyond 100 years. In addition, the use of a double clay cap separated by a graded granular filter enhances the ability of the cap to prevent percolation of precipitation. Any precipitation that percolates past the first clay barrier would tend to drain toward the drainage ditches at each end of the granular filter. The second cap should thus receive very little of the percolating precipitation. The use of a rip rap cover over the clay provides protection from both erosion and burrowing animals and would tend to retard the succession of deep rooted vegetation.

Items E and F were rejected because there is no reasonable assurance that they could prevent migration of water into the waste and retard migration of any resulting leachate significantly beyond a 100-year period. Item G was rejected based on the very unfavorable cost for such a structure (USDOE 1979 b).

Conceptual sketches of the caps, liners and underdrain system included as part of the selected alternative are shown in Figures 4-1 through 4-4 for the existing storage structures. Figure 4-1 is a plan view of the retrievable TRU waste storage area showing the gravity drain system around each waste storage building, the locations for the proposed soil lysimeters and additional monitoring wells. Figures 4-2, 4-3 and 4-4 show sectional and detail views of the drain system and mound covers for Buildings 7826 (drum storage), 7827 (stainless steel lined wells), 7834 (drum storage) and 7855 (concrete cask storage). Sectional views are not shown for Building 7829 (stainless steel lined wells) but they would be similar to those shown for Building 7827.

It is assumed that any additional storage structures required between now and 1995 (plus the structure required to house the buried casks after retrieval) would be similar in design to the existing structures and would be located in their immediate vicinity.

4.3 STRATEGY 3: RETRIEVE WASTE AND PROCESS FOR SHIPMENT TO A FEDERAL REPOSITORY

4.3.1 General Screening

In identifying alternatives for this strategy, numerous options are possible when all the combinations of waste retrieval, processing, waste immobilization, transportation and disposal methods are considered. To achieve a manageable number of realistic options for this strategy, the alternatives considered were, in general, limited to alternative processing/immobilization methods. The bases for this limitation are:

A. Waste retrieval methods are dictated by the type of storage (trench, building, etc.) and type of storage container (drum, cask, etc.). No significant advantages in cost or risk are expected if retrieval methods other than those specified in Subsection 4.3.4.1 are used.

B. Immobilization methods are limited, by the study guidelines, to basalt or glass.

C. No significant advantage in cost or risk is evident for truck transportation in comparison with rail. Therefore, the use of ATMX 600 railcars were selected since these have been designed to withstand severe accidents (see McDonald and Griffin, 1972, and Adcock and McCarthy, 1977, for additional information regarding the ATMX 600 railcar). Use of the rail loading facilities at the Oak Ridge Gaseous Diffusion Plant has been assumed for this study.

D. Only offsite disposal at a Federal repository is considered since the Oak Ridge Reservation is not under active consideration as a site for a Federal repository for TRU or high-level waste. In addition, there is insufficient data available to assess the viability of such an alternative.

In considering the processing alternatives, it was assumed that the current waste containers would not satisfy transportation requirements for offsite disposal because of possible degradation during the storage period. Thus, the processing alternatives considered consist of: a) overpacking (placing existing waste containers unopened into new containers); b) repackaging (opening of existing waste containers and placing contents into new containers); c) compaction; and d) incineration.

The type of compactor selected was a drum type compactor. The only significant advantage of a baler type compactor is a higher volume reduction factor for certain types of waste. This advantage is offset by the extra equipment and labor that would be required to package the bale for shipment.

The incinerator types considered were limited to the molten glass and rotary kiln incinerators. The rationale for this selection is documented in Section 10.0, Appendix C.

The proposed location of the facility site that would be required for the repackaging, compaction, or incineration operations is shown on Figure 4-5. This site is adjacent to the new Hydrofracture Facility.

4.3.2 Processing Considerations for Each Waste Type

The applicability of any of the above processing methods is dependent upon the characteristics of the waste and the interim storage methods used. The discussion that follows considers the alternatives available for each of the waste types.

Drums: The processing alternatives considered applicable for the waste stored in the drum buildings are: a) overpacking; b) compaction; and c) incineration. Overpacking would be accomplished using 0.314 cubic meter (83 gallon) drums. Repackaging was deleted as an alternative or this waste type since it does not offer any significant advantages in comparison to overpacking and is judged to have significant disadvantages with respect to cost and risk. Most of the waste stored in drums is both combustible and compactible and thus both incineration and compaction are viable processing options.

Casks: All four processing alternatives are considered applicable for the wastes stored in concrete casks. Overpacking the casks is considered as a potential alternative although it would require specially fabricated containers large enough to hold the casks. Repackaging the contents of the casks would allow the use of standard containers such as 0.208 cubic meter (55 gallon) drums. For those casks which contain large pieces of equipment or equipment racks, size reduction techniques could be used to enable their contents to be repackaged in drums. Compaction and incineration of the waste stored in casks are also considered as possible alternatives since a significant fraction of the waste is compactible and combustible.

Waste Packages from Stainless Steel Lined Wells: Overpacking is considered the only viable option for these waste packages. Because of the variety of waste package sizes, it would have to be performed on a case-by-case basis. Repackaging of the contents of the waste packages does not appear to offer any significant advantages with respect to overpacking the containers. Compaction and incineration were not considered as possible options since the waste, in general, is not compactible or combustible.

4.3.3 Identification of Alternatives

The above considerations have resulted in the identification of the following five processing alternatives for Strategy 3:

A. Alternative 3A: Overpack all of existing waste containers.

B. Alternative 3B: Repackage contents of waste stored in concrete casks; overpack drums and waste packages from lined wells.

C. Alternative 3C: Size reduce and compact contents of waste stored in drums and concrete casks; overpack waste packages from lined wells.

D. Alternative 3D: Incinerate contents of waste stored in drums and concrete casks in a molten glass incinerator; size reduce and repackage bulk metal items; overpack waste packages from lined wells.

E. Alternative 3E: Incinerate contents of waste stored in drums and concrete casks in a rotary kiln incinerator; size reduce bulk metal items; immobilize size reduced metal and incinerator residue using a basaltic slag; overpack waste packages from lined wells.

More detailed descriptions of each alternative together with the applicable waste retrieval methods are given below.

4.3.4 Conceptualization of Alternatives

4.3.4.1 Waste Retrieval

Recommended waste retrieval methods will vary depending on the manner in which waste is stored. A brief description of the recommended methods for each type of storage is as follows:

Drums: Normal material handling methods would be used since most of the drums are made of stainless steel and the storage method used permits the drums to be periodically checked and maintained.

Prior to initiating waste retrieval from the drum storage buildings, a general survey of working conditions in the area including visual and radiation surveys of the buildings and drums would be conducted. If any leaking or suspect drums are detected, plans for special handling of these drums would be initiated. After any unsafe conditions are corrected, the storage facility roofs would be removed utilizing a crane. Drums would again be inspected and monitored and lifted out of the drum storage building utilizing a twin drum lifting attachment on the crane. Figure 4-6 presents a block flow diagram summarizing the procedure to be followed for drum retrieval.

Buried Casks: Because it is not possible to determine the condition of the buried casks prior to waste retrieval operations, the retrieval method is based on the assumption that some of the drums may be leaking or in poor condition resulting in the potential for airborne transport of contamination during waste retrieval operations. Thus, waste retrieval would be performed in a portable building operated at negative pressure. After locating the trench of interest and ascertaining that safe working conditions exist in the vicinity of the trench, the area around the initial work location would be sufficiently leveled to permit erection of a portable building. The building would be similar to that shown in Figure 4-7 and would include personnel and vehicle airlocks and a HEPA filtration system. After negative pressure operation of the building has been achieved, a trench would be dug on both sides of the casks using a backhoe. The casks and surrounding soil would be monitored for contamination. If contaminated soil is detected, it would be placed in a container suitable for transport. After removal of the remaining soil around the casks, the casks would be lifted out of the trench using a mobile hydraulic boom crane ("cherry picker") and cleaned as necessary. Any leaking or suspect casks would be placed in an overpack suitable for local transport. If any cask has deteriorated to the point that it is not possible to lift the intact cask out of the trench, special handling procedures (such as placing the contents, pieces of the cask and any contaminated soil in one or more of the overpack containters) would be used. After retrieval at the given location is complete, the building would be disassembled. The contour of the area would be restored and the area would be reseeded with native vegetation. The entire procedure would be repeated at other trench locations until retrieval of the buried casks is complete. A block flow diagram summarizing retrieval of the buried casks is shown in Figure 4-8.

Stored Casks: Normal material handling methods would be used for retrieval since the storage method allows the casks to be periodically inspected and maintained. Prior to initiating retrieval operations, a survey of the working conditions in the area including visual and radiation surveys of the casks and buildings would be conducted. After working conditions have been determined to be satisfactory, the outer wall or gate and any inner walls within each storage bay would be removed. The casks would again be inspected and monitored and would be repaired and decontaminated as necessary. Removal of the casks from the building would be accomplished using a specially equipped forklift. A block flow diagram of the operational steps described above is shown in Figure 4-9.

Waste Packages in Lined Wells: Because of the nature of the storage method, periodic inspection of the waste containers is possible. Consequently, waste retrieval of these containers assumes that the containers have retained their integrity and would only require special materials handling procedures because of the high activity present. Working conditions in the area would be checked to assure safe conditions existed before waste retrieval operations begin. The concrete plug from the well of interest would be removed utilizing a crane. If information is not available from records on the size of the waste packages, it would be necessary to determine the size using mirrors and a ruled marker or more sophisticated methods. A shielded carrier sized for the waste package being retrieved would be placed over the well with the crane. The waste canister would be lifted into the carrier and the carrier would be closed. The process would be repeated until all packages are retrieved. Figure 4-10 is a block flow diagram which summarizes this retrieval process.

4.3.4.2 Alternative 3A: Overpacking

In reviewing the concepts to be included in this alternative, consideration was initially given to a facility in which overpacking of all of the existing waste containers could take place. This concept was rejected for overpacking the drums and casks since the cost of such a facility appeared to be unwarranted for the small advantage such a facility would provide in comparison to overpacking the casks and drums at the waste storage sites as they are retrieved.

Because of the nature of the waste packages in the lined wells, overpacking would require a hot cell facility with remote packaging capability for a variety of waste package sizes. The High Radiation Level Examination Laboratory (Building 3525) was chosen to overpack this waste material since most of these wastes were originally packaged in the facility (see Olsen, et al. 1963, for additional information about this facility). Building 3525 has the necessary equipment for performing the overpacking operations and, at least at present, has capacity available to include overpacking of these packages as part of its operation. The advantages of using Building 3525 in comparison to building a new facility for the limited task of overpacking these waste packages are obvious.

Based upon the above, the concept for Alternative 3A consists of: 1) overpacking the drums and casks at the waste storage area as they are retrieved; and 2) overpacking the waste packages from the lined wells using equipment in Building 3525. Alternative 3A is outlined in the block flow diagram shown in Figure 4-11 and is described below.

It is anticipated that 0.314 cubic meter (83 gallon) drums could be used as the overpacking containers for the 0.208 cubic meter drums. The overpack containers for the casks would have to be specially fabricated. Some of the casks will also require additional shielding in order to meet transportation requirements. Additional shielding for the drums is not anticipated to be required. For this alternative, the additional cask shielding was assumed to be provided by a transport shield with dimensions large enough to accommodate the overpacked casks. The only function of the transport shield is to reduce surface dose rates to allowed limits. Empty overpack containers and transport shields would be stored in a warehouse facility similar to the present drum staging facility (Building 7823) or the supply building adjacent to the waste storage area (Building 7824) and transferred to the waste retrieval locations as required.

Waste retrieval for the drums and stored and buried casks would be performed as described in Subsection 4.3.4.1. As each container is retrieved, it would be lowered into an overpack container which would then be sealed and inspected to determine its suitability for offsite transport. If an overpack has radiation levels exceeding transportation requirements, the overpack would be loaded into a transport shield.

The waste packages from the lined wells would be retrieved as described in Subsection 4.3.4.1. The shielded carriers from the retrieval area would be transported to Building 3525. The waste packages would be transferred into the hot cells in Building 3525 using existing equipment. The waste packages would be overpacked in containers selected as appropriate to accommodate the original packaging. Each overpack would be inspected, placed in a shielded carrier and placed on a truck for transport to the rail loading facility at the Oak Ridge Gaseous Diffusion Plant. At the loading facility, the shielded carriers would be loaded into ATMX 600 railcars and shipped to the Federal repository.

After all of the waste packages were shipped, the negative pressure buildings and associated equipment used in retrieving the buried casks are the only items and facilities that would need to be decontaminated and decommissioned. It is anticipated that these buildings and the equipment could be readily decontaminated and would not require packaging and shipment to the Federal repository.

4.3.4.3 Alternative 3B: Repackaging

For the reasons discussed in Subsection 4.3.2, repackaging of the waste is considered as a potential alternative only for the waste stored in concrete casks. Thus, this alternative consists of repackaging the contents of the concrete casks and overpacking the drums and waste package from the lined wells. The operational steps included in this alternative are outlined in a block flow diagram shown in Figure 4-12.

The overpacking operations would be performed as described in the previous subsection. The repackaging operations would require a facility designed for remote handling of the waste. Figures 4-13 and 4-14 present a conceptual design of such a repackaging facility. This facility would include an air filtration system with a minimum decontamination factor of 10^6.

Waste retrieval of the casks would be performed as described in Subsection 4.3.4.1. The casks would be loaded on a truck and transported to the repackaging facility. The truck would enter the facility via an airlock. The casks would be inspected to assure that they could be safely handled. They would then be unloaded using the bridge crane shown in Figure 4-13 and placed in the interim storage area. The truck would be checked for contamination, decontaminated if necessary, and returned to the waste retrieval area.

Each cask would be transferred to the cask dumping area where it would be opened and its contents unloaded onto the sorting conveyor. The empty casks would be transferred to the decontamination area, decontaminated and transported to the burial grounds. The decontamination solutions used in either cask or truck decontamination would be stored temporarily in a waste tank at the basement elevation. The contents of the tank would be sampled and periodically pumped to the ILW waste tanks adjacent to the hydrofracture facility where they would become part of the waste to be processed through the Intermediate Level Liquid Waste System at ORNL.

Items from the casks that are too large to fit inside a 0.208 cubic meter (55 gallon) drum would be transferred to the size reduction area adjacent to the sorting conveyor and cut to fit in the drums. The type of equipment used for the cutting operations would depend on the characteristics of the oversized pieces and could include such items as saws, torches and shears. The size reduced pieces would be returned to the sorting conveyor.

All waste items would be assayed for fissile and transuranic content prior to being packaged. An assay system capable of performing this operation is not presently commercially available but it is anticipated that systems being developed at other DOE laboratories (Umbarger and Cowder 1975, Nieschmidt and Vegors 1978) will be available by the time waste processing operations begin.

Each drum would be sealed and inspected to determine if it is suitable for shipping. After inspection, the drum would be placed in the full drum storage area. As shown in Section A-A in Figure 4-14, the drum fill, capping and inspection stations are on a conveyor just below grade elevation. This allows a control room at grade for all other operations described above. It also permits automatic packaging operation once new drums are loaded on the drum conveyor.

Procedures for shipping the repackaged waste to a Federal repository are the same as described for Alternative 3A in Subsection 4.3.4.2.

After all of the waste packages are shipped, the cask repackaging facility and negative pressure buildings would be decontaminated and decommissioned. It is anticipated that the negative pressure building and equipment could be readily decontaminated and would not require packaging and shipment to the Federal repository. However, it is expected that a portion of the repackaging facility where the waste is not in an enclosed container would be contaminated to the point that decontamination would not be possible. It is estimated that this portion of the facility would result in 75 cubic meters of D&D waste that potentially would have to be shipped to the Federal repository. D&D of the repackaging facility could be simplified by including such things as easily decontaminated surfaces and equipment that dismantle into easily handled components in the facility design.

4.3.4.4 Alternative 3C: Compaction

Compaction is considered a potential alternative for the waste stored in drums and concrete casks (see Subsection 4.3.2). Thus, this alternative consists of compacting the contents of the casks and drums and overpacking the waste packages from the lined wells. The operational steps included in this alternative are summarized in the block flow diagram shown in Figure 4-15 and are discussed in more detail below.

Waste retrieval would be performed as described in Subsection 4.3.4.1. After retrieval, the waste packages from the lined wells would be overpacked in Building 3525 as described in Subsection 4.3.4.2. The casks and drums would be loaded on a truck and transported to a compaction facility. A conceptual design of this facility is shown in Figures 4-16 and 4-17. The facility would include an air filtration system with a minimum decontamination factor of 10^6.

At the compaction facility, unloading and related operations would be similar to those described in Subsection 4.3.4.2 for the repackaging facility with the following exceptions: 1) the facility design allows truck entry without a separate truck bay airlock; and 2) unloading of the truck could be performed with either a forklift or bridge crane. After unloading, the casks and drums would be placed in one of the interim storage areas.

A transfer cart would be used to move the casks and drums from the interim storage area, through an airlock, and under the coverage of the bridge crane in the processing portion of the facility. The crane would be used to transfer the cask or drum to the sorting area. The container would be opened and its contents, except for large items, would be unloaded into the presorting bin. Large items would be transferred directly to the size reduction area.

The empty casks and drums would be transferred to the decontamination area. Procedures related to decontamination and disposal of the drums and casks would be similar to those described in Subsection 4.3.4.3 for the cask repackaging facility with the exception that the only drums that would be disposed of are those that are not reusable.

The contents of the presorting bin would be fed onto a conveyor where a manipulator would be used to remove items that have the potential for interfering with operation of the compactor (e.g., a piece of pipe, etc.). The removed items would be placed in the size reduction area. Saws, torches, shears, etc. would be used in reducing sorted items to a size where they could be mixed with the compactible waste. After assay for fissile and transuranic content, the sorting conveyor would be used to transfer the waste to the compactor storage bin.

Drums into which the waste would be compacted would be loaded on the drum conveyor at the grade elevation. The conveyor would be indexed so that empty drums could be precisely located under the compactor. Waste from the compactor storage bin would be fed into the empty drum. The compactor would compact the waste in the drum and more waste would be added and the process repeated. To control "spring-back" of the compacted waste, a procedure similar to that described in Herald and Luthy 1976 could be used. The conveyor would be used to transfer the filled drum to the area where it would be sealed and inspected to determine suitability for shipping. The conveyor would then transport the drums to the unshielded storage area. Those drums that require shielded storage would be transferred using the bridge crane covering the shipping/storage area.

Shipping procedures for the drums are similar to those described in Subsection 4.3.4.3 for the repackaging facility.

D&D considerations for the compaction facility are also similar to those described in Subsection 4.3.4.3 for the repackaging facility. The volume of D&D waste that potentially would have to be shipped to the Federal repository is estimated to be approximately 100 cubic meters.

4.3.4.5 Alternative 3D: Incineration Using a Molten Glass Incinerator

As discussed in Subsection 4.3.2, incineration is considered as an alternative for the waste stored in drums and concrete casks. The waste packages stored in the lined wells would be overpacked as described in Subsection 4.3.4.2. A block flow diagram, summarizing the operations included in this alternative, is shown in Figure 4-18. Figures 4-19, 4-20 and 4-21 present a conceptual design of the molten glass incineration facility.

The casks and drums would be retrieved from storage as described in Subsection 4.3.4.1 and loaded on a truck for transport to the incineration facility. Unloading operations would be similar to those described in Subsection 4.3.4.3 for the repackaging facility with the exceptions that the conceptual design of the molten glass incineration facility allows truck entry without the use of a truck bay airlock and allows unloading with a forklift, if desired.

To begin processing operations, cask and drums in interim storage are placed on the conveyor shown in Figure 4-19. The conveyor transports the containers into the transfer area where they would be lifted up to the second floor using the underhung crane servicing that area. The airlocks and hatch shown would be interlocked so that only one could be opened at any one time.

The containers would be opened and their contents unloaded into the sorting bin/ conveyor using the gantry crane and manipulators. The empty containers would be lowered through the hatch back into the waste container transfer area. The conveyor would be used to transfer them to the decontamination area. After the containers had been satisfactorily decontaminated, they would be returned to the interim storage area. The receiving truck bay would be used for shipment of the decontaminated containers to the burial grounds or to other areas for reuse.

Large items and bulk metal pieces in the waste that could not be satisfactorily processed in the incinerator would be removed from the waste conveyor for size reduction. A check to determine whether bulk metal items are present in the sealed 3.8 liter (1 gallon) containters used in storing waste in the concrete casks would be performed using a metal detector. Containers with such items would be removed to the metal objects hopper as detected. All other sealed 3.8 liter containers would be opened using a guillotine shear to assure proper incineration of their contents. After the waste was assayed for fissile and transuranic content, the conveyor would transport the sorted waste to the incinerator feed mechanism. The feed mechanism would be designed so that the metal containers could be placed on a special shelf above the molten glass where they would oxidize over a period of three hours (L. Penberthy, Private Communication, 1980). The oxidized containers and the remainder of the sorted waste would be fed directly to the molten glass. Gases resulting from the incineration process would be processed through a secondary combustion chamber to assure complete combustion (Bonner, et al. 1980). The gases from the secondary combustion chamber would be processed through a scrubbing system and two sets of HEPA filters prior to discharge through the stack. The filtration system would have a minimum decontamination factor of 10^6.

The molten glass containing the waste residue would be periodically cast into drums at the fill station. Empty drums for this purpose would be transferred from the new drum storage area using the conveyor. The filled drums would be cooled and assayed to determine the quantity of fissile material remaining in the incinerator. The drums would be sealed and inspected to determine their suitability for shipping. They would then be placed in one of the storage areas until shipped. Shipping procedures would be similar to those described in Subsection 4.3.4.3 for the repackaging facility.

The large items removed when the waste is sorted would be assayed using portable instrumentation and reduced to a size that would easily fit into a 0.208 cubic meter (55 gallon) drum. The type of size reduction technique used for a particular item would depend on its characteristics but could include the use of saw, torches, shears, etc. The size reduced pieces would be placed in the metal objects-hopper which would periodically be fed into 0.208 cubic meter drums in the packaging alley on the first floor of the facility. An inert material such as sand would be added to the drum if necessary to prevent movement of metal objects in the drum during transport. The drums would be sealed inspected, and placed in one of the storage areas. Shipping procedures would be similar to those used for the drums containing the glass/waste residue mixture.

D&D considerations for the molten glass incineration facility are similar to those described in Subsection 4.3.4.3 for the repackaging facility. The volume of D&D waste that potentially would have to be shipped to the Federal repository is estimated to be approximately 100 cubic meters.

4.3.4.6 Alternative 3E: Incineration Using a Rotary Kiln

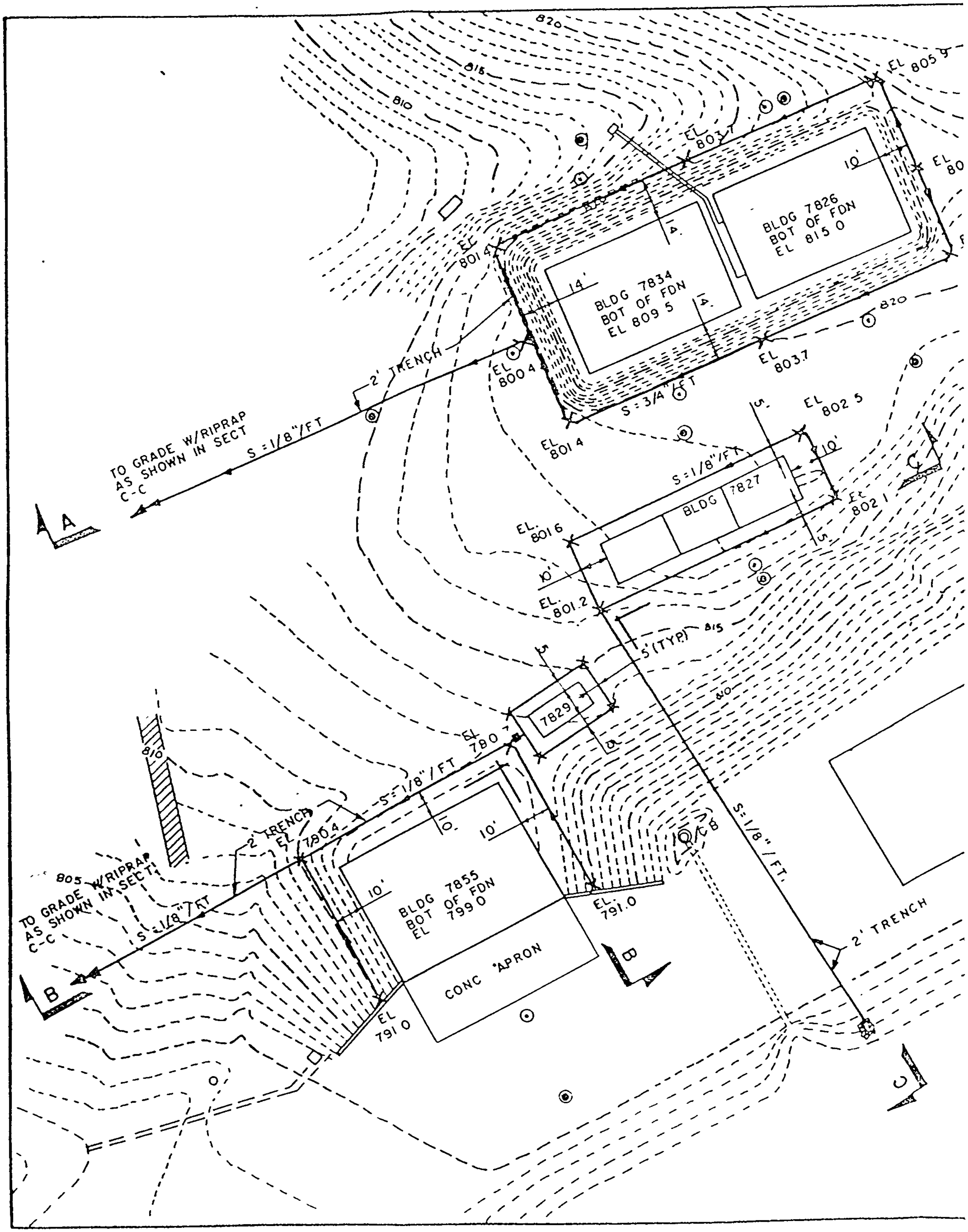
As discussed in Subsection 4.3.2, incineration is considered as an alternative for the waste stored in drums and concrete casks. The waste packages stored in the lined wells would be overpacked as described in Subsection 4.3.4.2. A block flow diagram summarizing the operations included in this alternative is shown in Figure 4-18. Those steps not explicitly labeled either "Molten Glass Incinerator" or "Rotary Kiln" are applicable to both alternatives. A conceptual design of the rotary kiln facility is shown in Figures 4-22, 4-23 and 4-24.

Most of the operations in the rotary kiln facility are similar to those described previously for the molten glass facility. The only significant difference is that the end product of incineration is a mixture of ash and noncombustibles (primarily metal). Based on the study guidelines (see Section 1.0) and the assumed repository waste acceptance criteria (see Section 10.0, Appendix B) the ash/noncombustibles mixture would have to be immobilized in either glass or basalt. Since the presence of unoxidized metals in the incinerator residue makes the use of glass as an immobilizing agent infeasible without further processing of the metal, basalt immobilization was selected for this alternative.

The basalt immobilization concept uses a molten slag at temperatures high enough to incorporate the metals and other incinerator residue into the slag mixture. The resulting solid waste form when the slag is cast and cooled is similar to the expected end product of the slagging pyrolysis incinerator being considered for processing TRU waste stored at the Idaho National Engineering Laboratory.

The basalt immobilization was developed as the result of a series of studies being performed in support of that effort (Flinn, et al. 1979). These studies used simulated INEL waste feed and soil native to the INEL. The resulting solidified slags are termed iron-rich basalt vitrophyre. The initial results of the studies indicate that the solidified slag appears to be a high strength, leach resistant, chemically stable waste form close to the composition of natural basalt.

The conceptual design of the rotary kiln facility incorporates the use of a slag immobilization unit in which the appropriate mixture of soil and additives would be melted. The residue from the incinerator and the sized reduced metal items would be periodically fed into the slag immobilization unit. The casting of the slag and the remainder of the operation is similar to that described for the molten glass incineration facility (see Subsection 4.3.4.5).



820
815
810
EL 805.9
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BLDG 7826
BOT OF FDN
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BLDG 7834
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EL 801.4
14'
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EL 800.4
2' TRENCH
S = 3/4"/FT
TO GRADE W/RIPRAP
AS SHOWN IN SECT
C-C
S = 1/8"/FT
A
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EL 801.4
S = 1/8"/FT
BLDG 7827
EL 802.1
C
EL 801.6
EL 801.2
5'(TYP)
815
810
7829
EL 780.7
S = 1/8"/FT
2' TRENCH
EL 780.4
805
TO GRADE W/RIPRAP
AS SHOWN IN SECT
C-C
S = 1/8"/FT
B
BLDG 7855
BOT OF FDN
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EL 791.0
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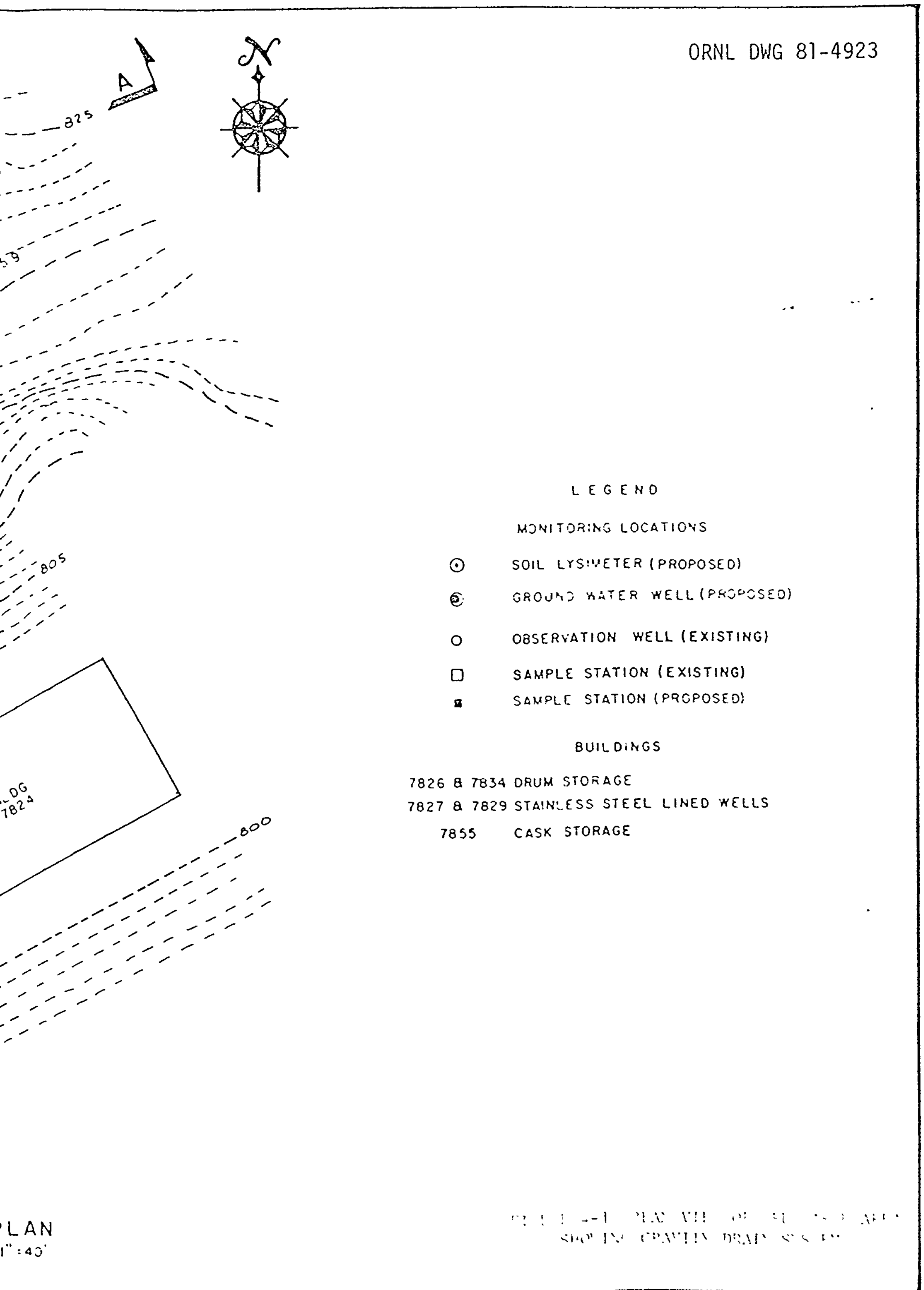
2' TRENCH
C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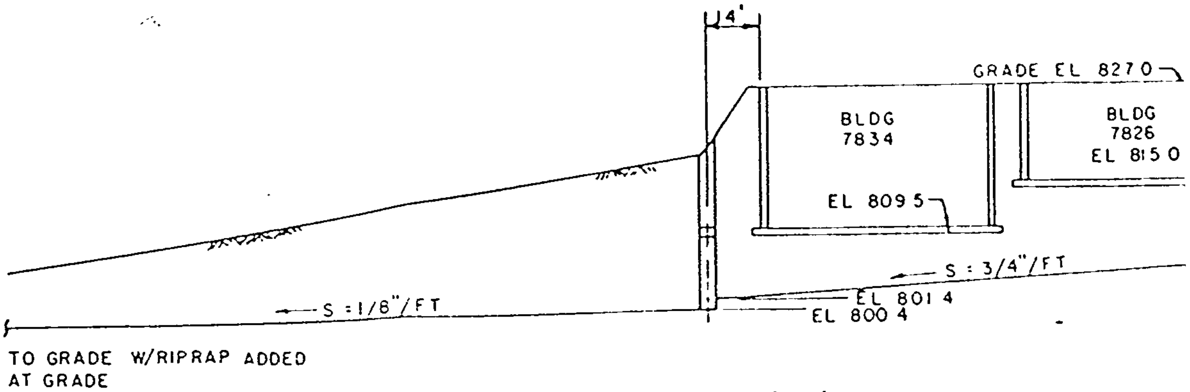
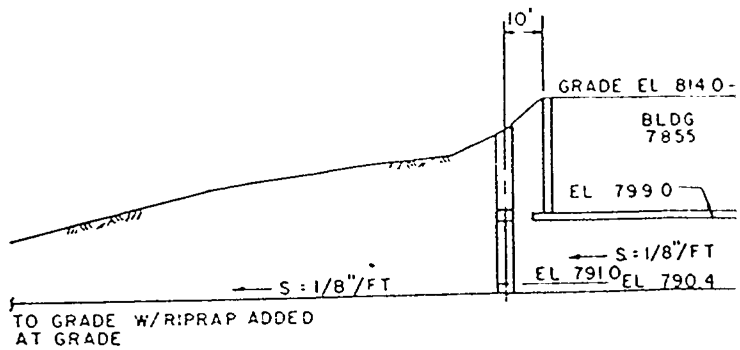
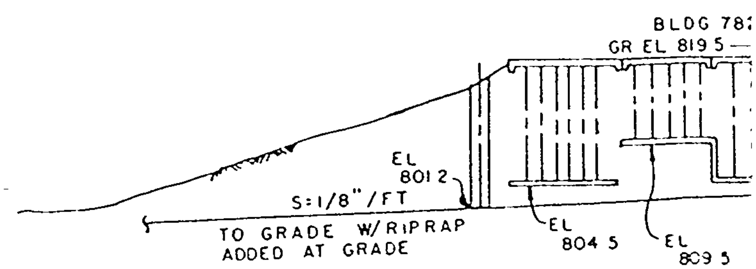
A
825
805
800
BLDG 7824
LEGEND
MONITORING LOCATIONS
SOIL LYSIMETER (PROPOSED)
GROUND WATER WELL (PROPOSED)
OBSERVATION WELL (EXISTING)
SAMPLE STATION (EXISTING)
SAMPLE STATION (PROPOSED)
BUILDINGS
7826 & 7834 DRUM STORAGE
7827 & 7829 STAINLESS STEEL LINED WELLS
7855 CASK STORAGE
PLAN
1" = 40'



SECTION A-A

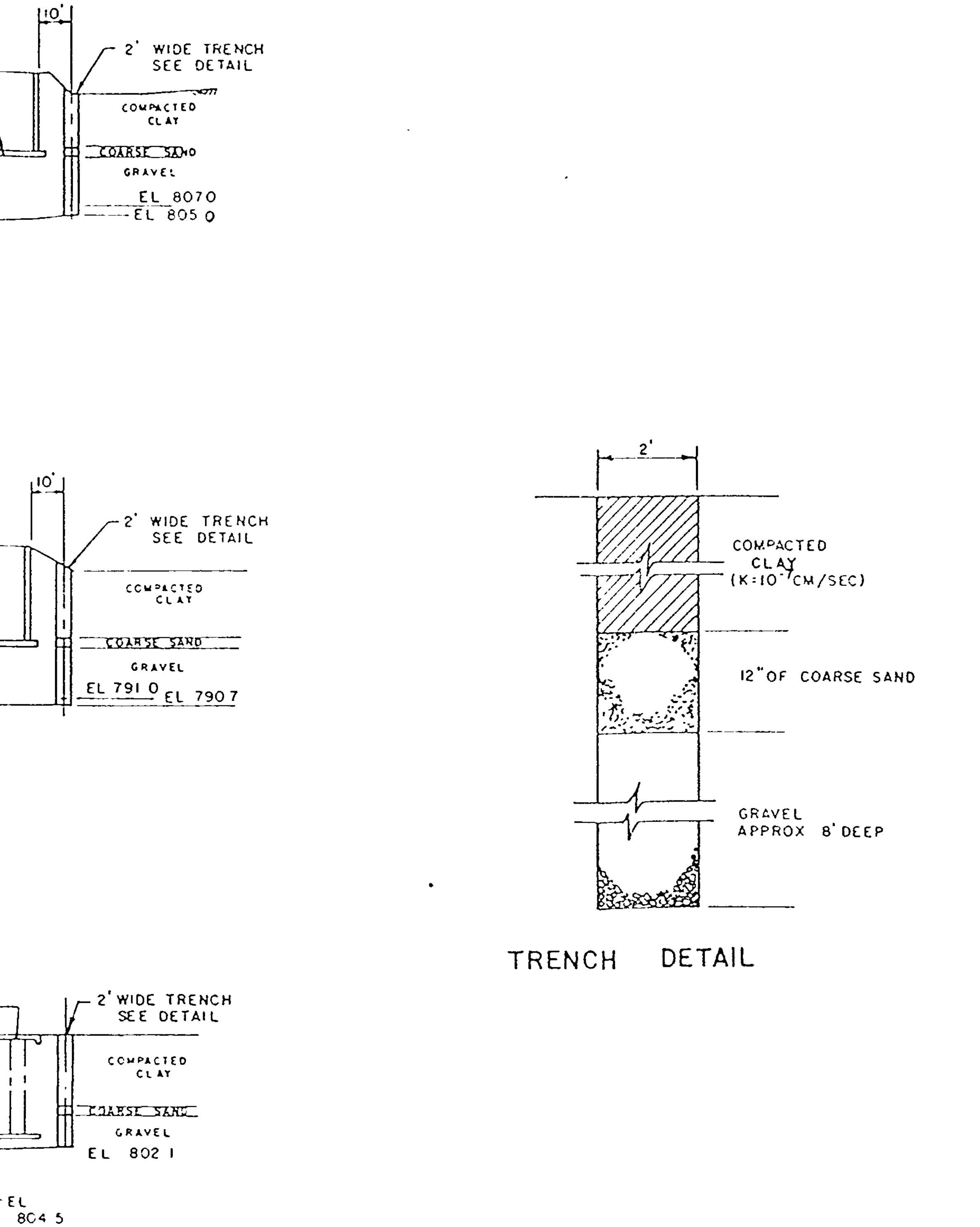


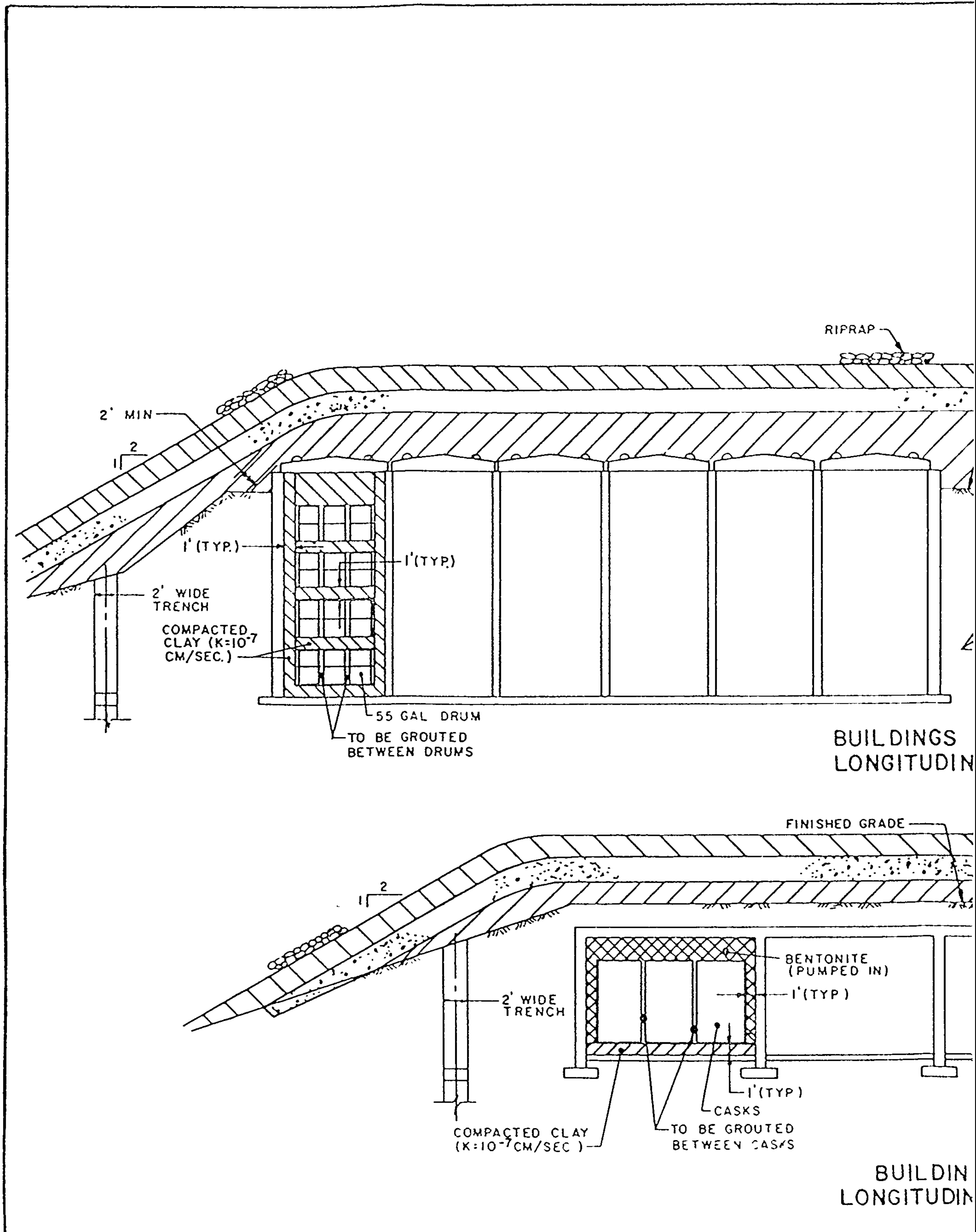
SECTION B-B



SECTION C-C

ORNL DWG 81-4924




RIPRAP
2' MIN
1 2
1' (TYP.)
1'(TYP.)
2' WIDE TRENCH
COMPACTED CLAY (K=10^-7 CM/SEC.)
55 GAL DRUM
TO BE GROUTED BETWEEN DRUMS
BUILDINGS
LONGITUDIN
FINISHED GRADE
1 2
BENTONITE (PUMPED IN)
1'(TYP)
2' WIDE TRENCH
1'(TYP)
CASKS
TO BE GROUTED BETWEEN CASKS
COMPACTED CLAY (K=10^-7 CM/SEC)
BUILDIN
LONGITUDIN

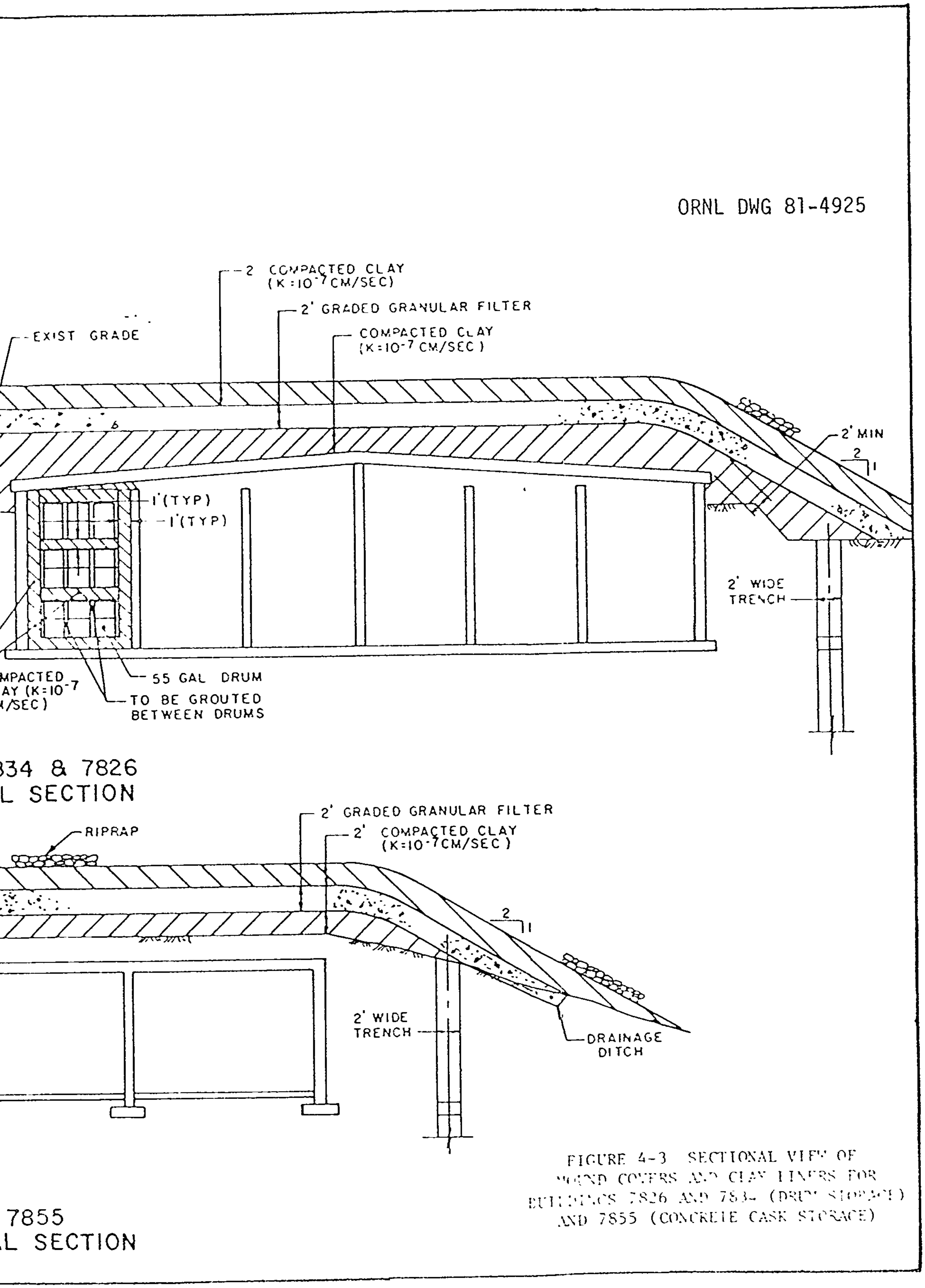
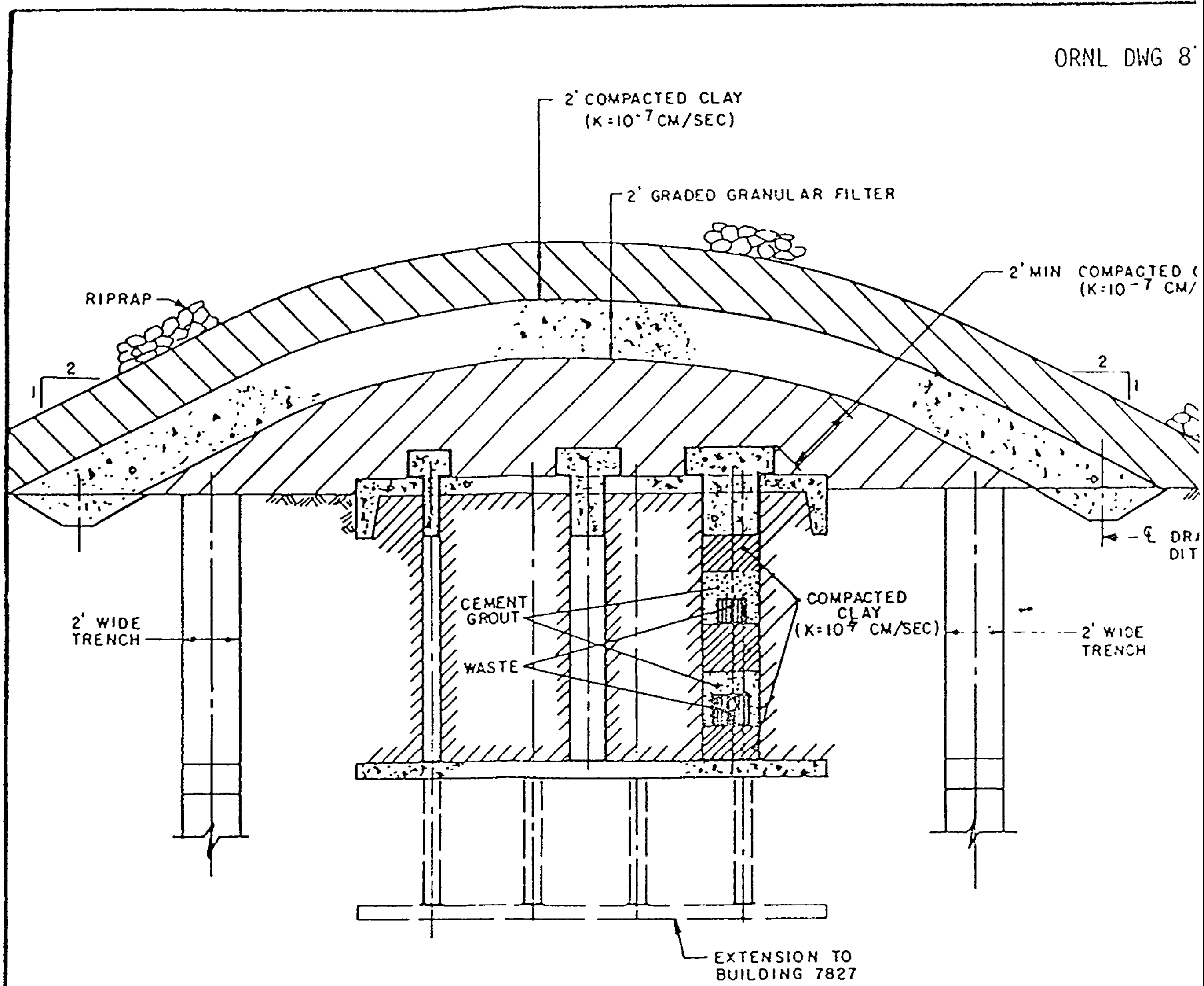


FIGURE 4-3 SECTIONAL VIEW OF MOUND COVERS AND CLAY LINERS FOR BUILDINGS 7826 AND 7834 (DRUM STORAGE) AND 7855 (CONCRETE CASK STORAGE)



BUILDING 7827
CROSS SECTION

4926

FIGURE 4-4 SECTIONAL VIEW OF MOUND COVERS AND CLAY LINERS FOR BUILDING 7827 (STAINLESS STEEL LINED WELLS)

ORNL DWG 81-4918

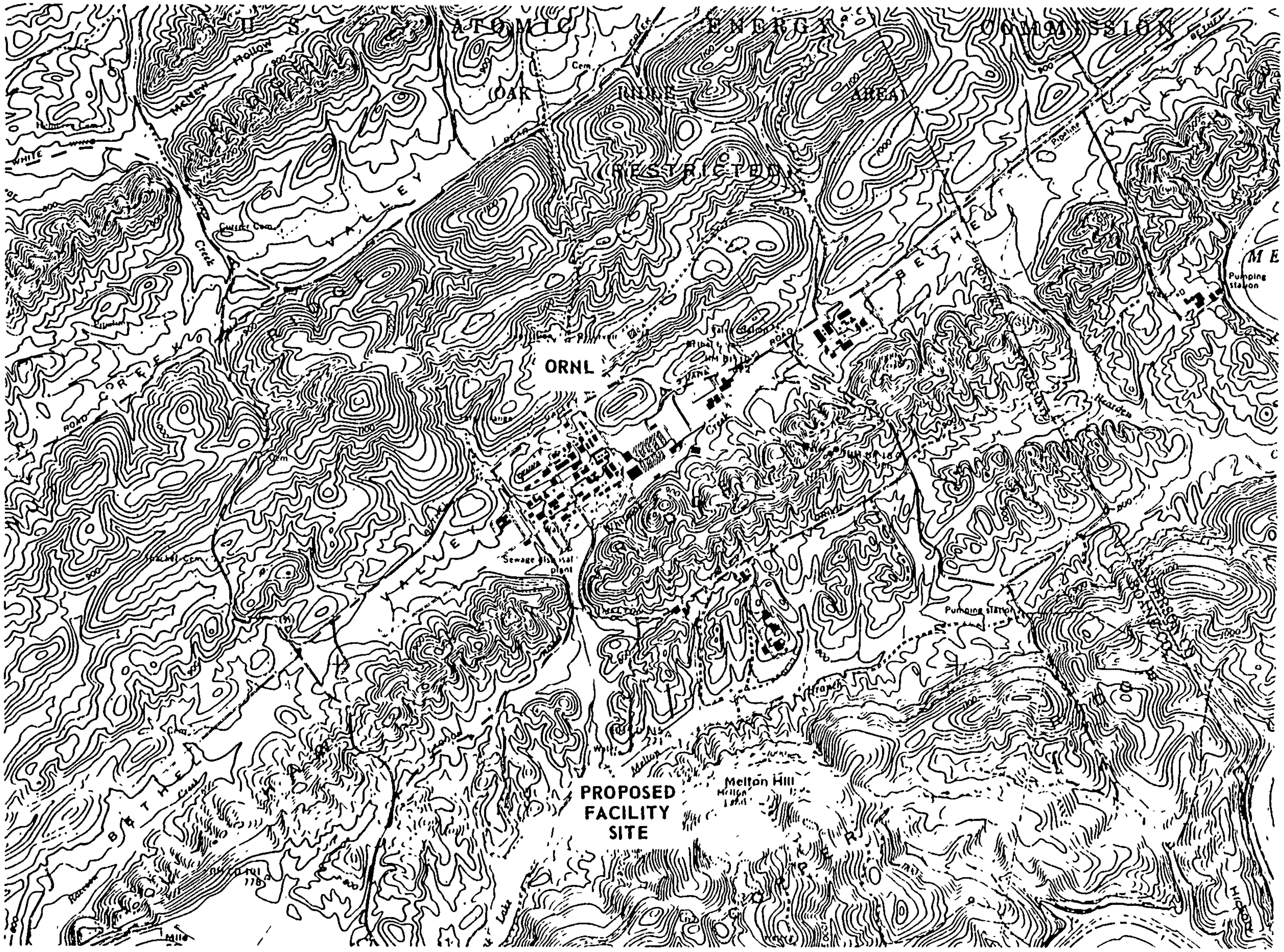


FIGURE 4-5 LOCATION OF PROPOSED PROCESSING FACILITY SITE

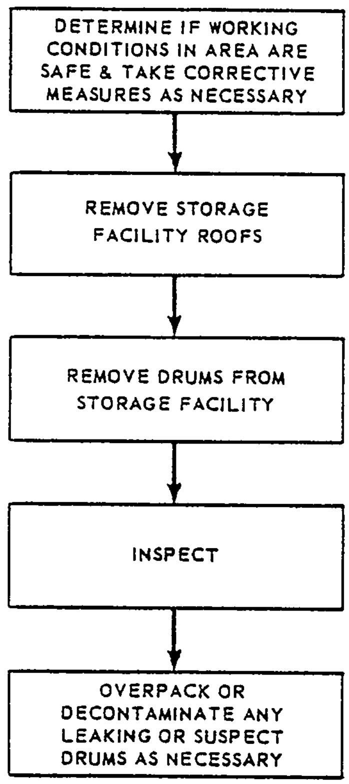
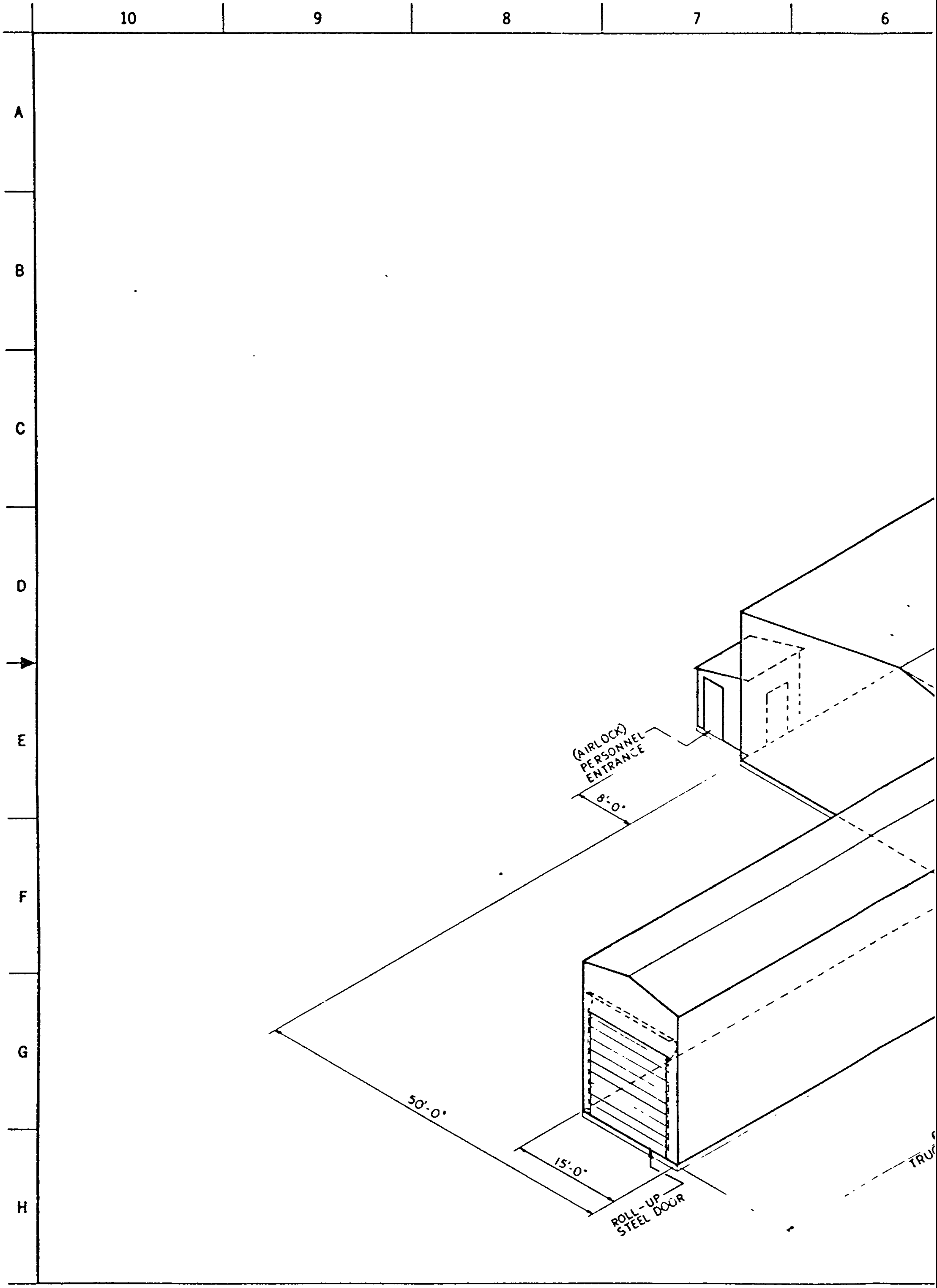


FIGURE 4-6 BLOCK FLOW DIAGRAM FOR RETRIEVAL OF STORED DRUMS


10
9
8
7
6
A
B
C
D
E
F
G
H
(AIRLOCK) PERSONNEL ENTRANCE
8'-0"
50'-0"
15'-0"
ROLL-UP STEEL DOOR

ORNL DWG 81-4927

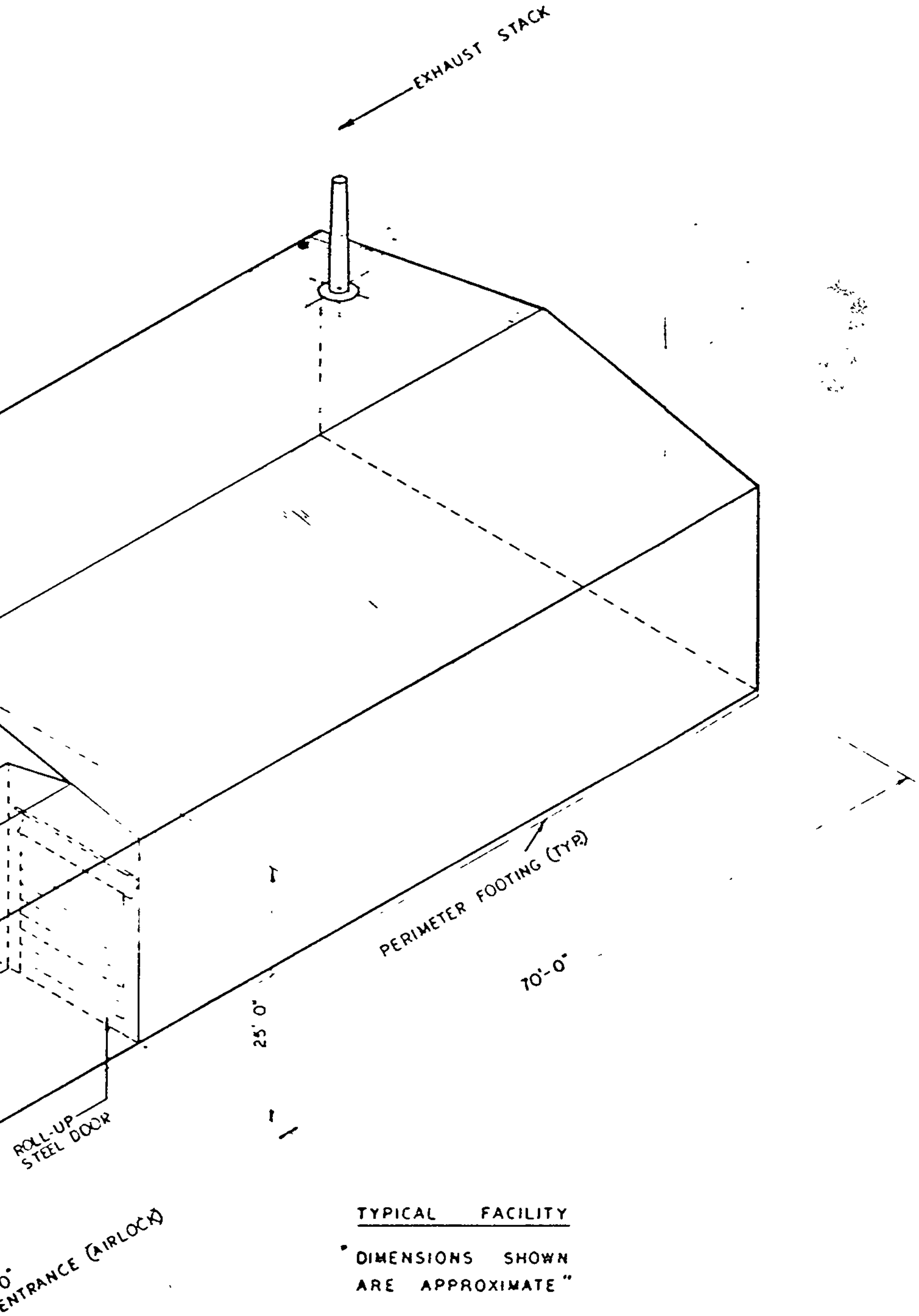


FIGURE 4-7 NEGATIVE PRESSURE BUILDING FOR CONTROLLED RETRIEVAL

PORTABLE RECOVERY BUILDING

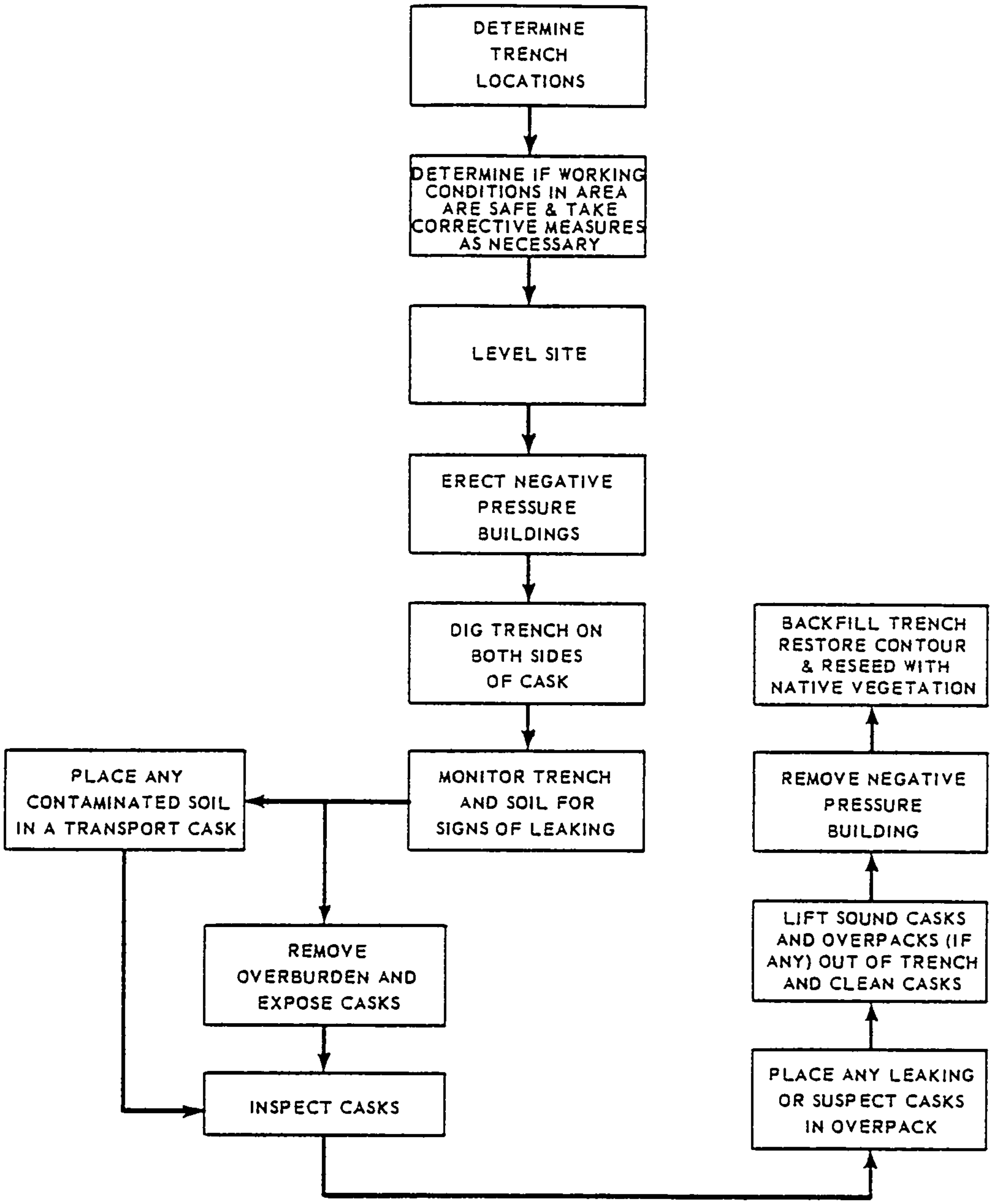


FIGURE 4-8 BLOCK FLOW DIAGRAM FOR RETRIEVAL OF BURIED CASKS

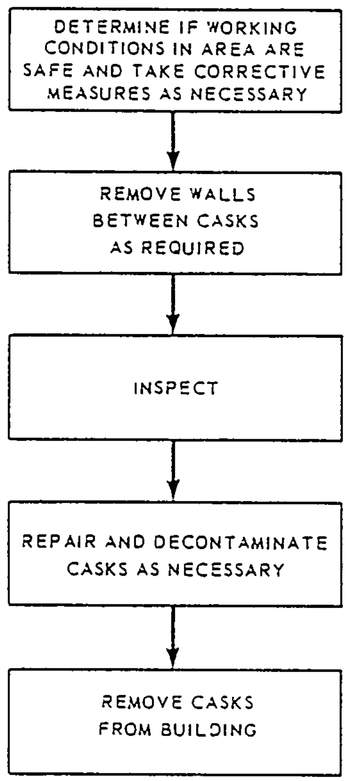


FIGURE 4-9 BLOCK FLOW DIAGRAM FOR RETRIEVAL OF STORED CASKS

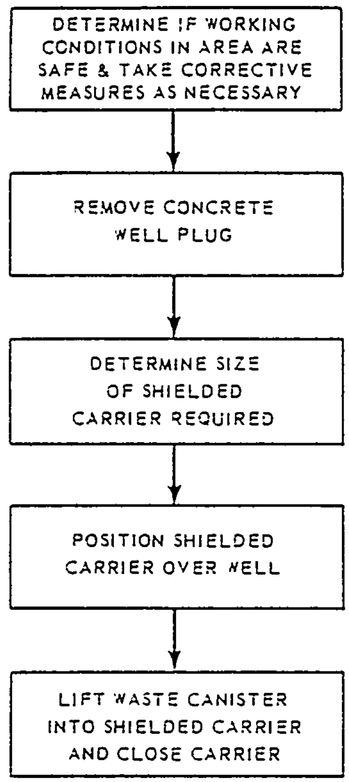


FIGURE 4-10 BLOCK FLOW DIAGRAM FOR RETRIEVAL OF WASTE PACKAGES FROM STAINLESS STEEL LINED WELLS

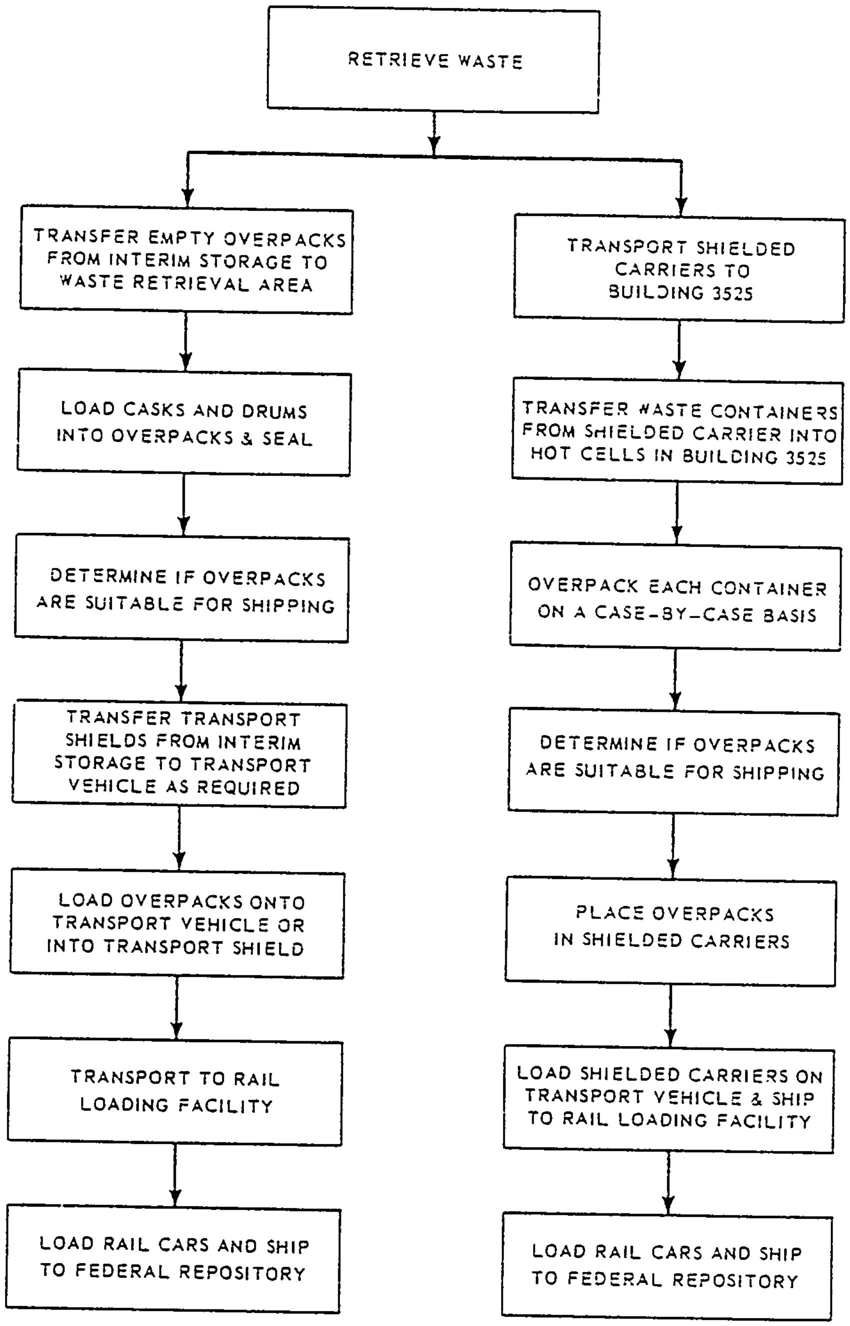


FIGURE 4-11 BLOCK FLOW DIAGRAM FOR ALTERNATIVE 3A: OVERPACKING

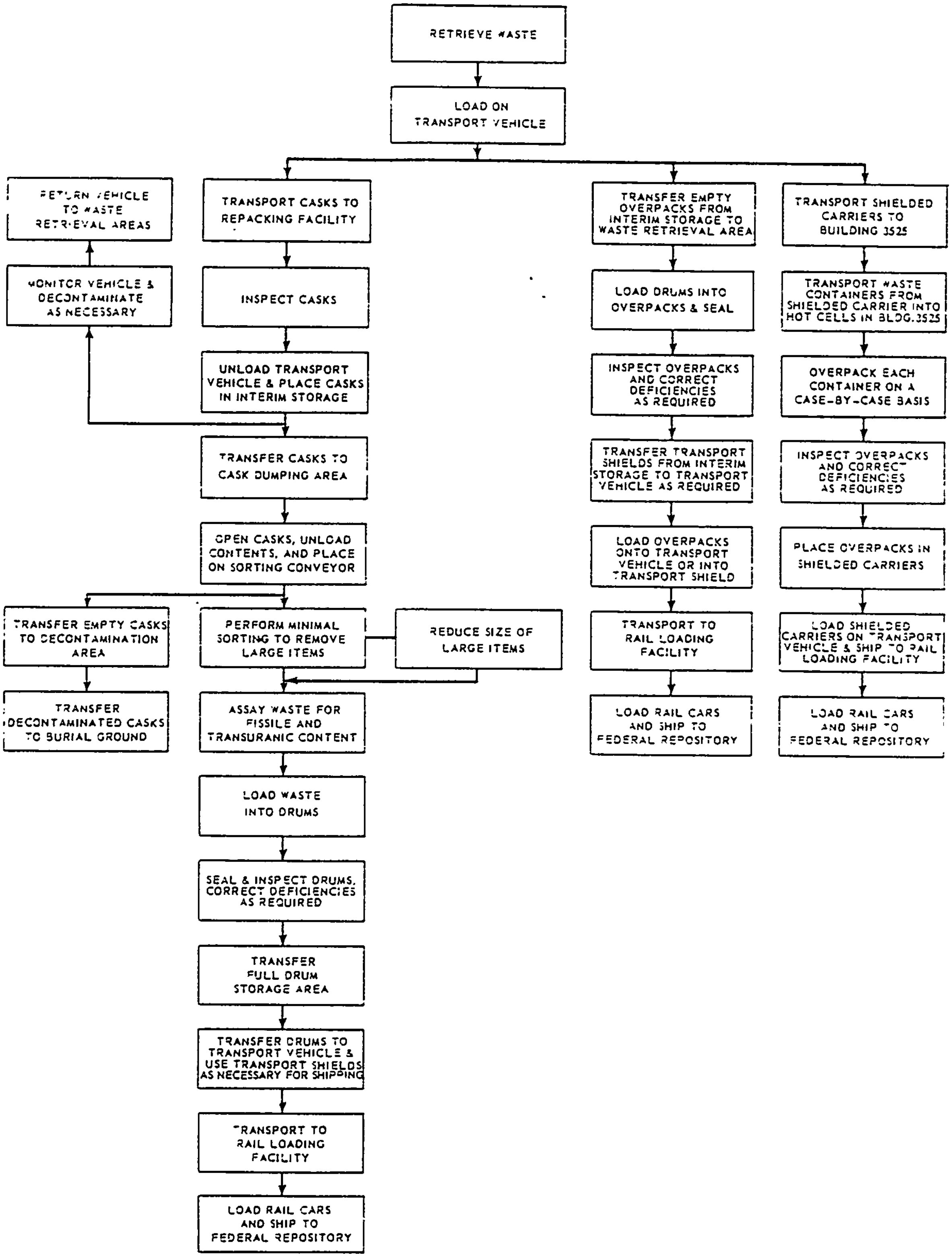
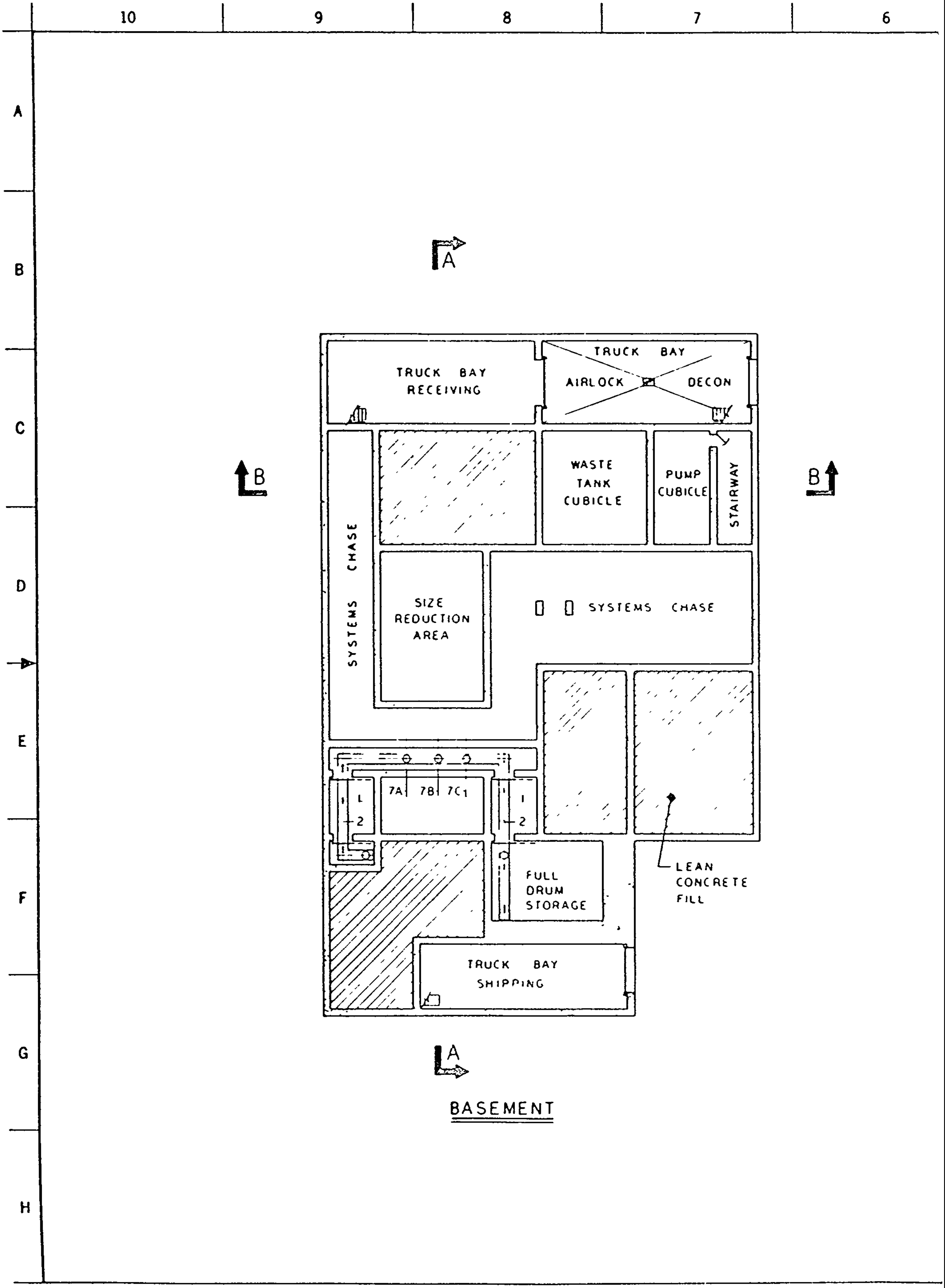


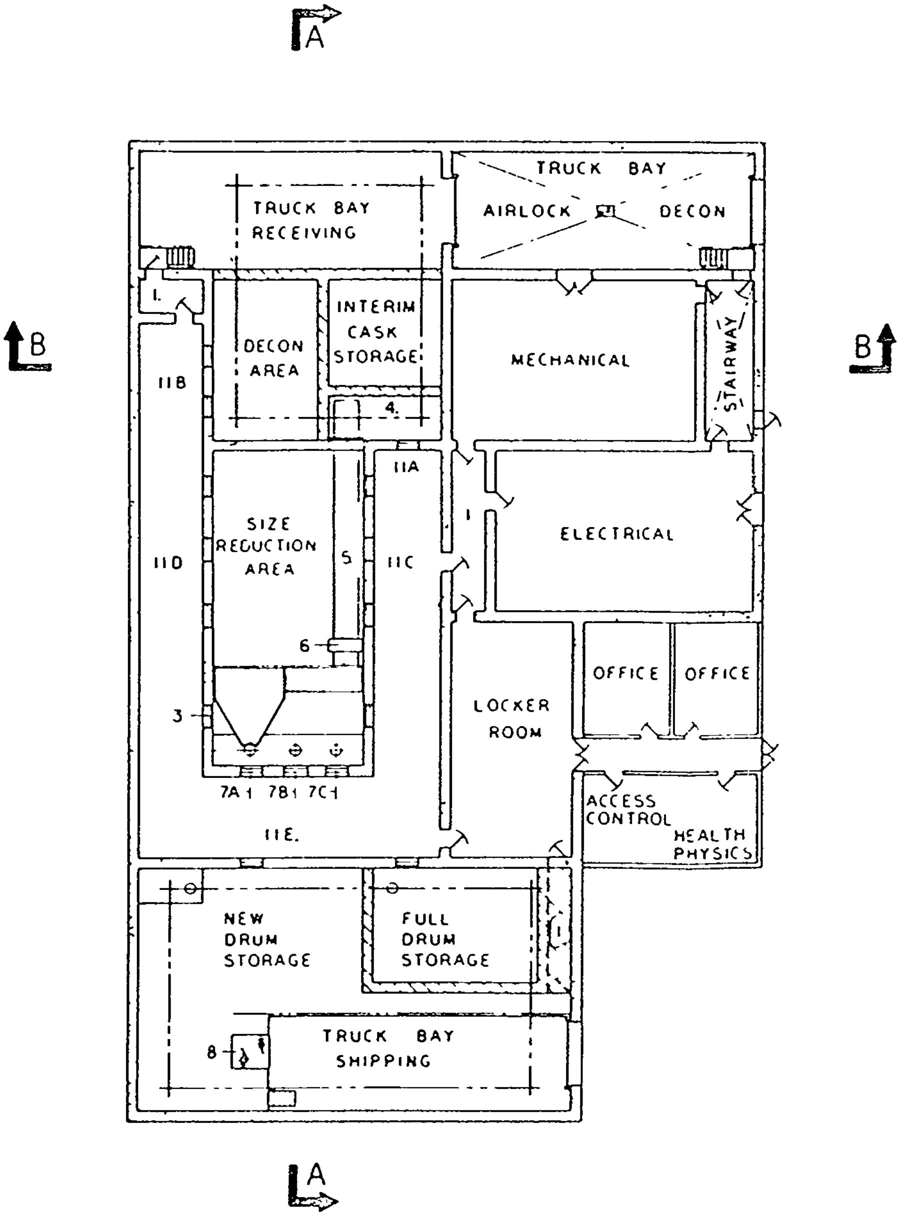
FIGURE 4-12 BLOCK FLOW DIAGRAM FOR ALTERNATIVE 3B: REPACKAGING



10
9
8
7
6
A
B
C
D
E
F
G
H
A
B
B
TRUCK BAY RECEIVING
TRUCK BAY
AIRLOCK
DECON
WASTE TANK CUBICLE
PUMP CUBICLE
STAIRWAY
SYSTEMS CHASE
SIZE REDUCTION AREA
SYSTEMS CHASE
7A
7B
7C
1
2
1
2
FULL DRUM STORAGE
LEAN CONCRETE FILL
TRUCK BAY SHIPPING
A

BASEMENT

ORNL DWG 81-4928

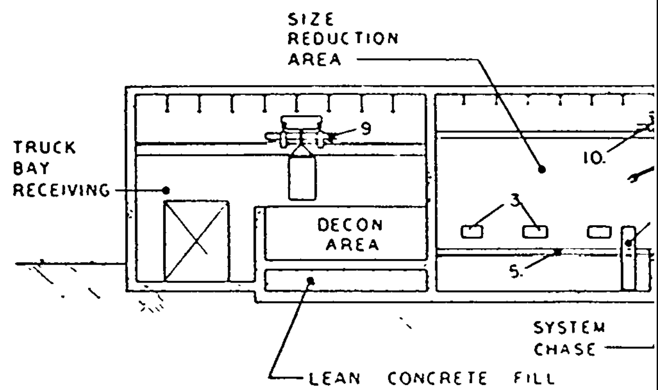


PLAN AT GRADE

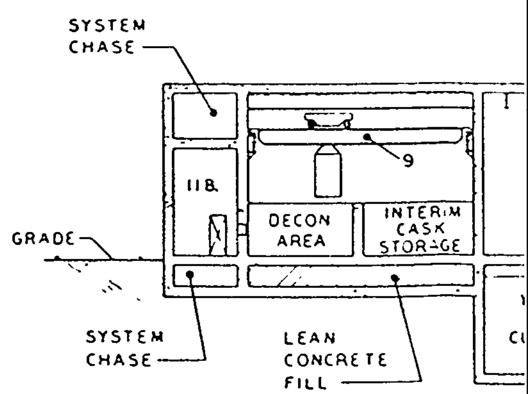
1 AIRLOCK
2 DRUM CONVEYOR
3. LEAD GLASS WINDOWS (TYPICAL 16 PLACES)
4. CASK DUMPING AREA
5. SORTING CONVEYOR
6 WASTE ASSAY INSTRUMENTATION
7. PACKAGING ALLEY
   A. FILL STATION
   B. CAPPING STATION
   C. INSPECT-MONITOR-DECON
8. HYDRAULIC DOCK BOARD
9. BRIDGE CRANES
10. MANIPULATOR CRANE
11. CONTROL ROOMS
   A. CASK DUMPING
   B. CASK DECON
   C SORTING
   D. SIZE REDUCTION
   E. PACKAGING

FIGURE 4-13 PLAN VIEWS OF REPACKING FACILITY

CASK REPACKAGING FACILITY PLANS



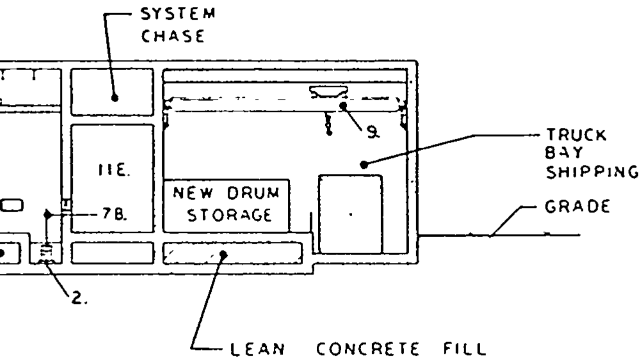
SECTION A



SECTION B

ORNL DWG 81-4929

2. DRUM CONVEYOR
3. LEAD GLASS WINDOWS (TYPICAL 6 PLACES)
5. SORTING CONVEYOR
6 WASTE ASSAY INSTRUMENTATION
7B. CAPPING STATION
9. BRIDGE CRANES
10. MANIPULATOR CRANE
11. CONTROL ROOMS
B. CASK DECON
E. PACKAGING



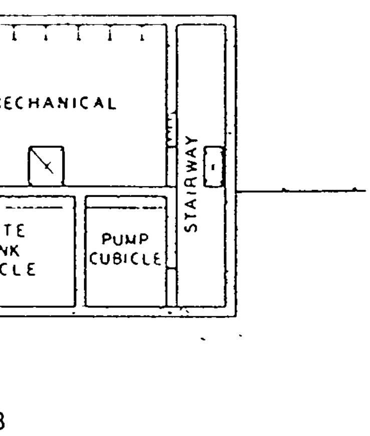


FIGURE 4-14 SECTIONAL VIEWS OF REPACKING FACILITY

CASK REPACKAGING FACILITY SECTIONS

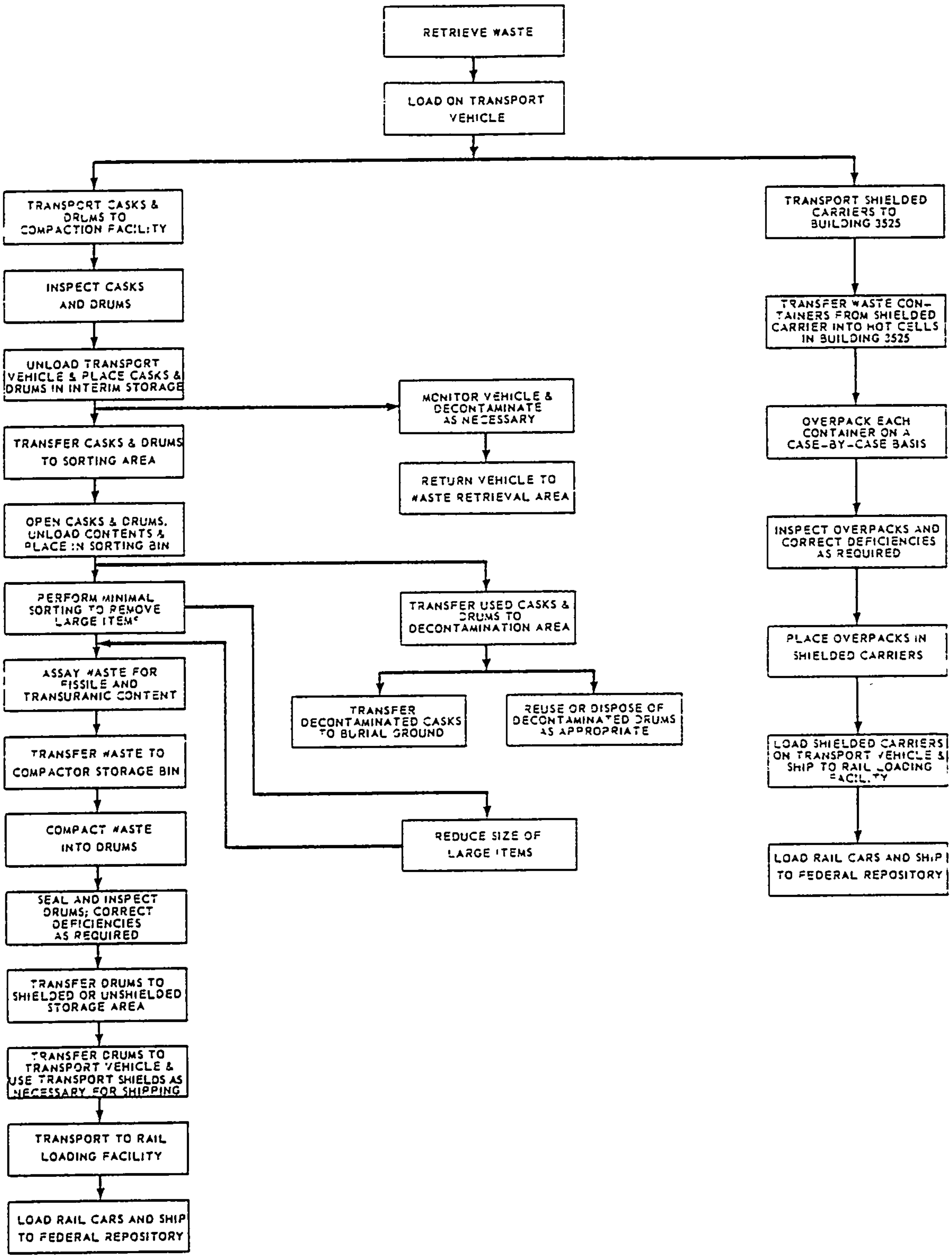
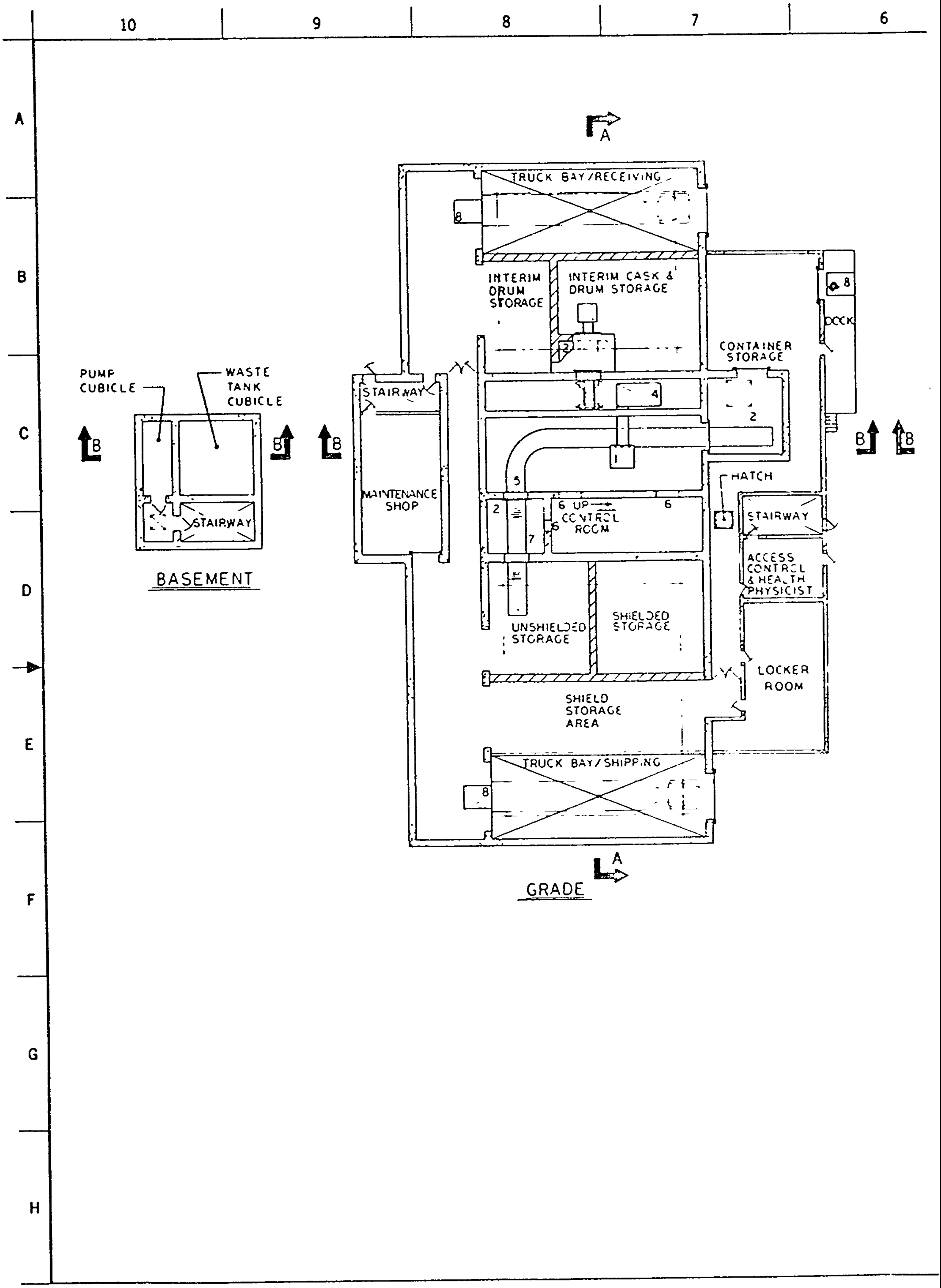
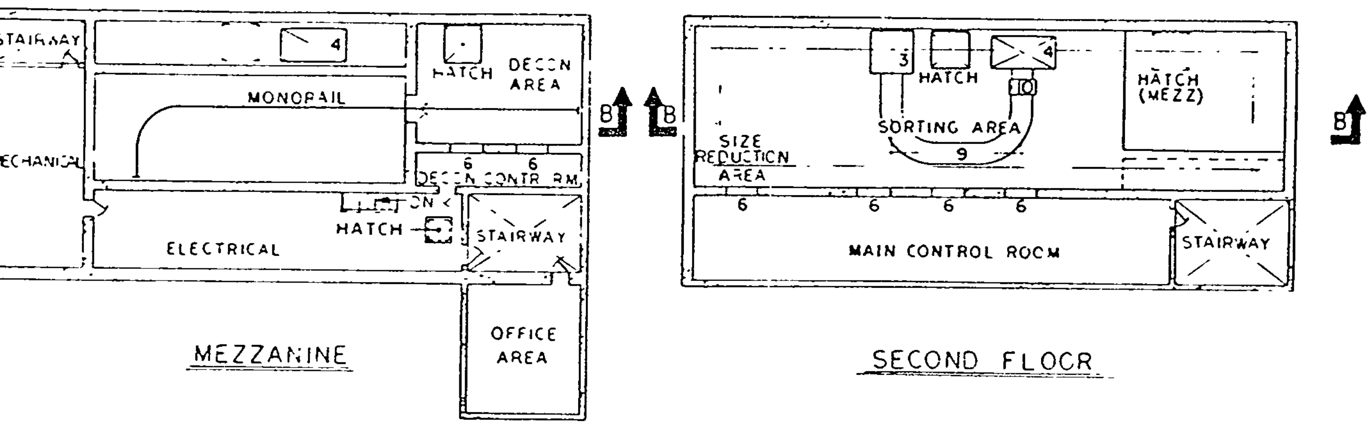


FIGURE 4-15 BLOCK FLOW DIAGRAM FOR ALTERNATIVE 3C: COMPACTION



10
9
8
7
6
A
B
C
D
E
F
G
H
PUMP CUBICLE
WASTE TANK CUBICLE
STAIRWAY
BASEMENT
TRUCK BAY/RECEIVING
INTERIM DRUM STORAGE
INTERIM CASK & DRUM STORAGE
CONTAINER STORAGE
DOCK
STAIRWAY
MAINTENANCE SHOP
HATCH
UP
CONTROL ROOM
STAIRWAY
ACCESS CONTROL & HEALTH PHYSICIST
UNSHIELDED STORAGE
SHIELDED STORAGE
LOCKER ROOM
SHIELD STORAGE AREA
TRUCK BAY/SHIPPING
GRADE

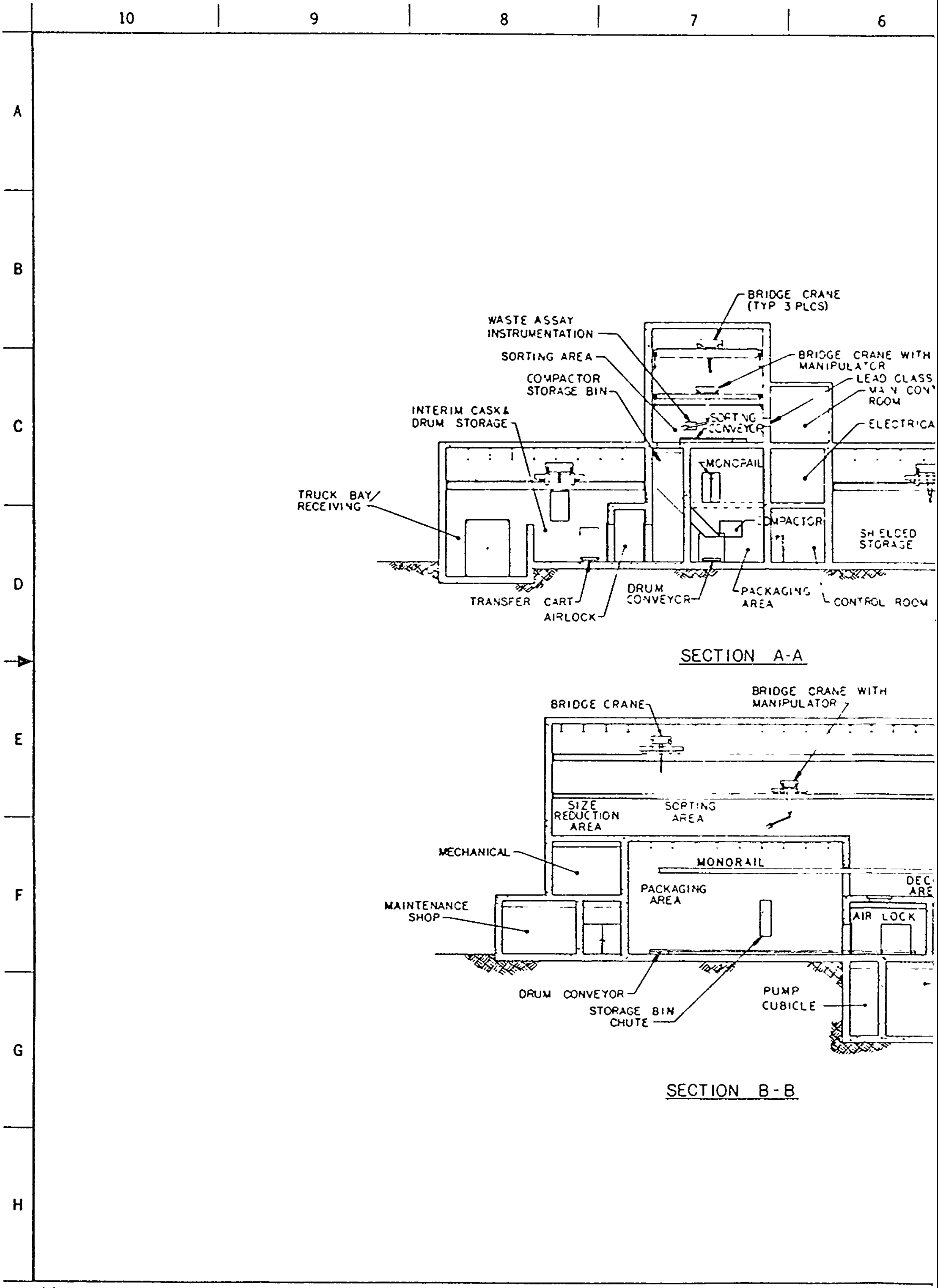
ORNL DWG 81-4930



1 COMPACTOR
2 AIRLOCK
3 PRE SORTING BIN
4 COMPACTOR STORAGE BIN
5 DRUM CONVEYOR
6 LEAD GLASS WINDOW
7 SEAL, INSPECTION MONITORING & DECON AREA
8 HYDRAULIC DOCK BOARD
9 SORTING CONVEYOR
10. WASTE ASSAY INSTRUMENTATION

FIGURE 4-16 PLAN VIEWS OF COMPACTION FACILITY

COMPACT FAC W/SIZE REDUCT CAPABIL



10
9
8
7
6
A
B
C
D
E
F
G
H
BRIDGE CRANE (TYP 3 PLCS)
WASTE ASSAY INSTRUMENTATION
SORTING AREA
BRIDGE CRANE WITH MANIPULATOR
COMPACTOR STORAGE BIN
LEAD GLASS
MAIN CONT ROOM
INTERIM CASK & DRUM STORAGE
SORTING CONVEYOR
ELECTRICA
MONORAIL
TRUCK BAY/ RECEIVING
COMPACTOR
SHIELDED STORAGE
TRANSFER CART
DRUM CONVEYOR
PACKAGING AREA
CONTROL ROOM
AIRLOCK
SECTION A-A
BRIDGE CRANE
BRIDGE CRANE WITH MANIPULATOR
SIZE REDUCTION AREA
SORTING AREA
MECHANICAL
MONORAIL
PACKAGING AREA
MAINTENANCE SHOP
AIR LOCK
DRUM CONVEYOR
PUMP CUBICLE
STORAGE BIN CHUTE
SECTION B-B

ORNL DWG 81-4931

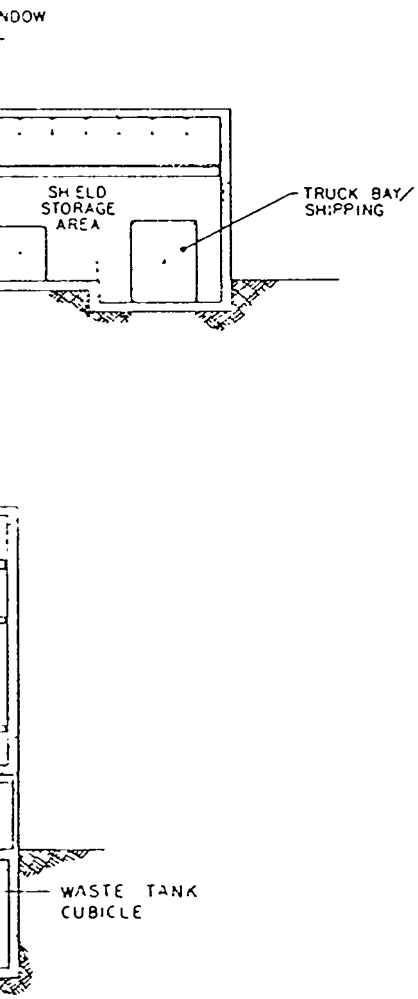


FIGURE 4-17 SECTIONAL VIEWS
OF COMPACTION FACILITY

COMPACT FAC W/SIZ REDUCT CAP-SECT

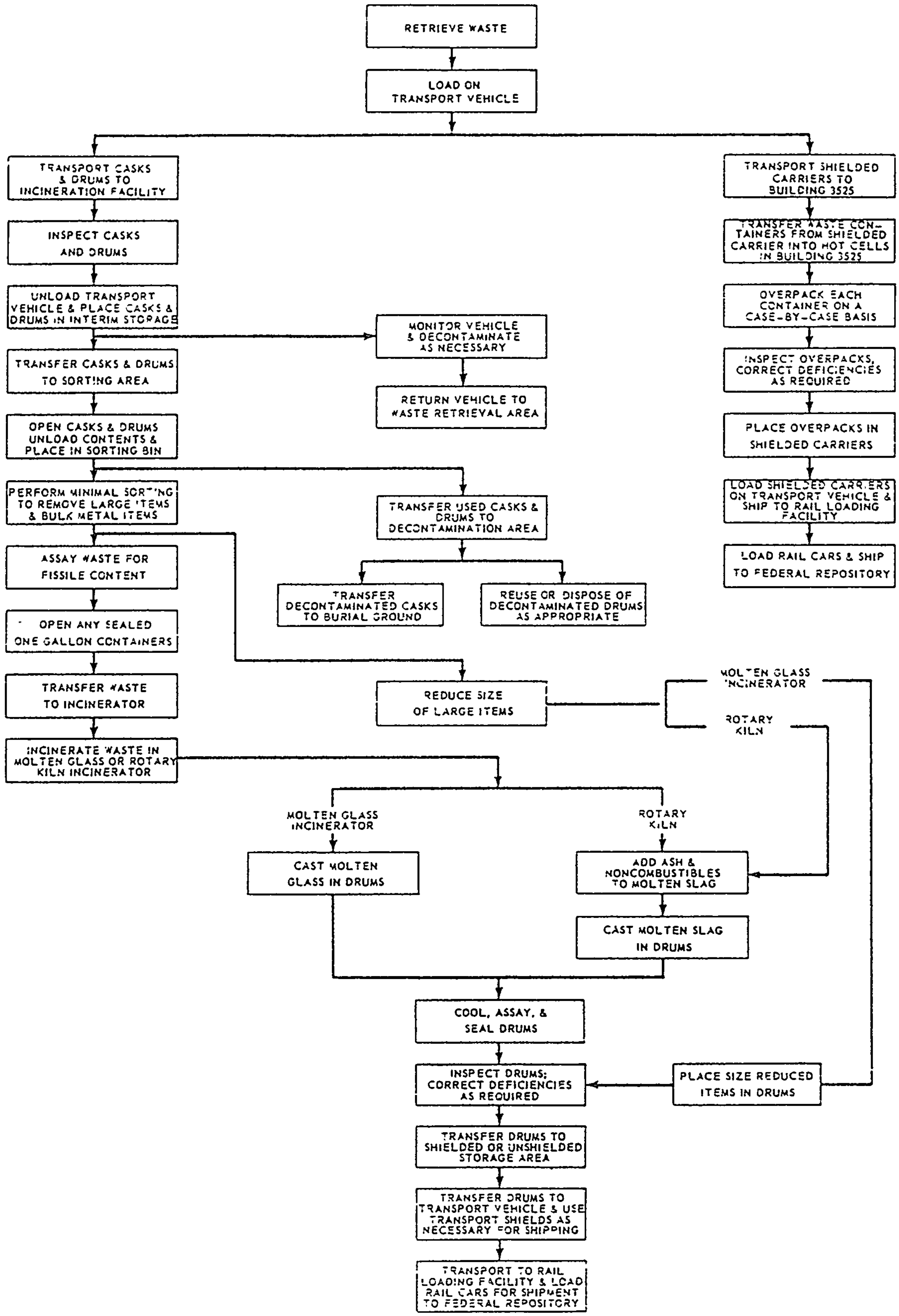
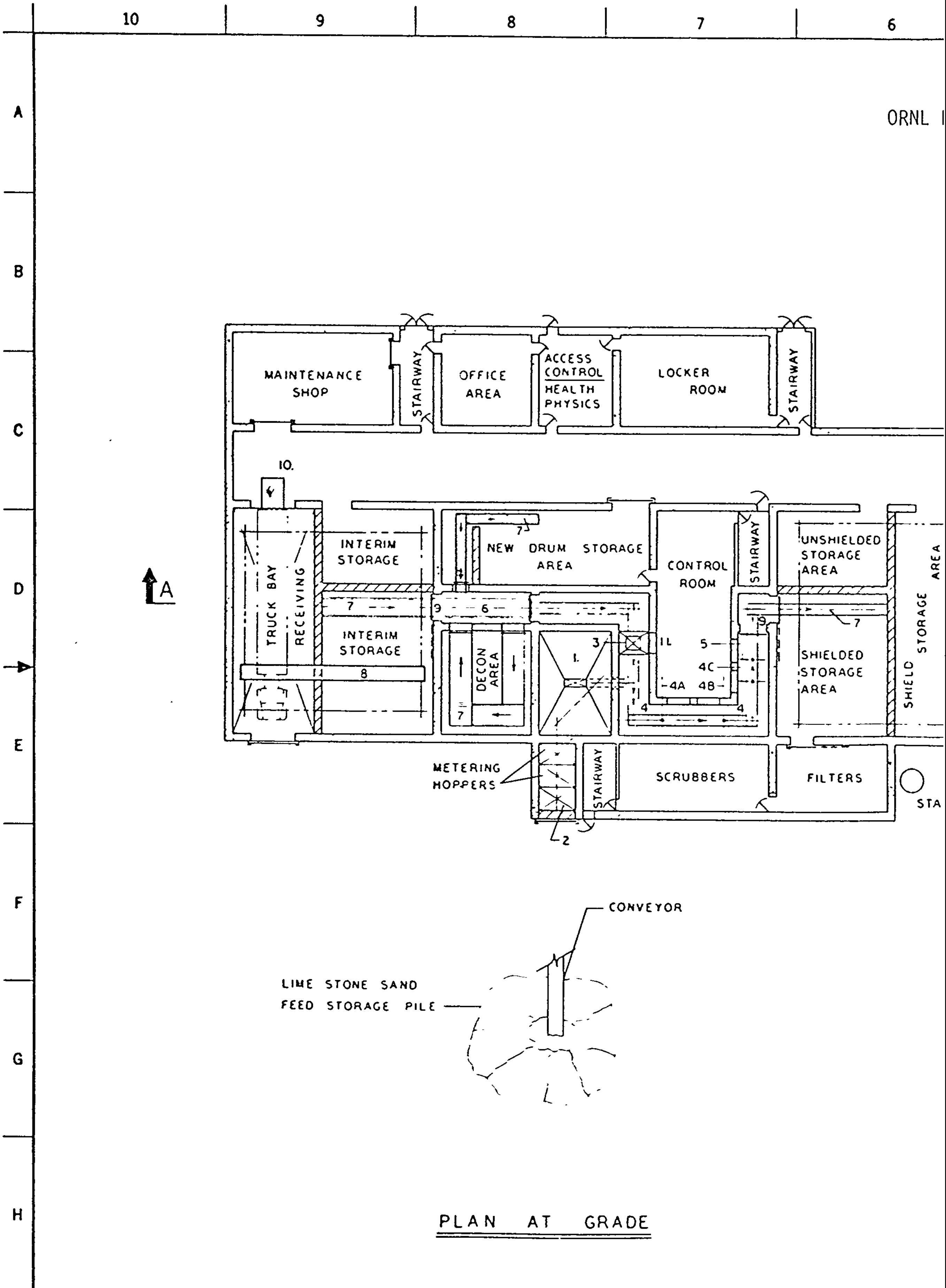


FIGURE 4-18 BLOCK FLOW DIAGRAM FOR ALTERNATIVES 3D AND 3E: INCINERATION



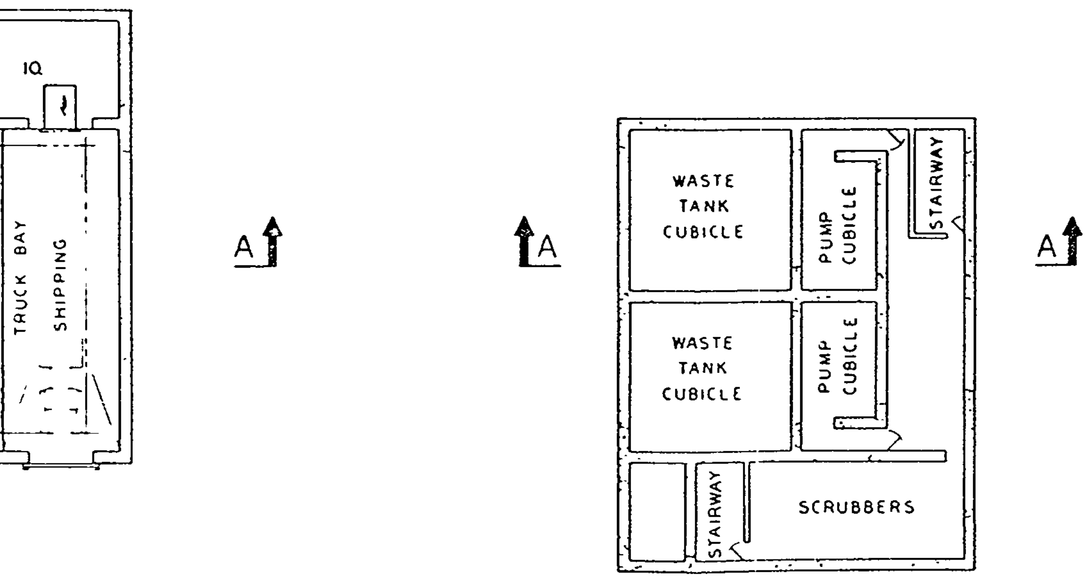
PLAN AT GRADE

5 4 3 2 1

DD

G 81-4932

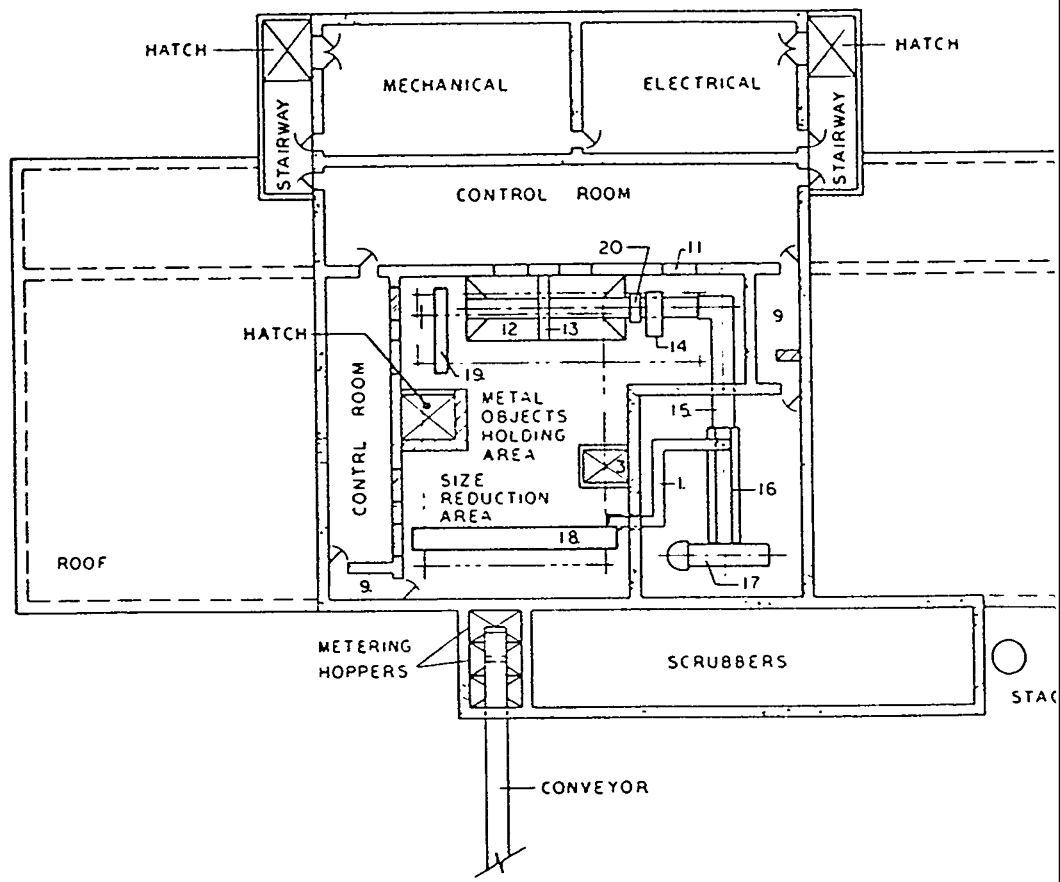
1. GLASS FRIT STORAGE HOPPER
2. GLASS FRIT UNLOADING STATION
3. METAL OBJECTS HOPPER & DRUM FILL STATION
4. PACKAGING ALLEY
4A FILL STATION
4B Q A STATION
4C CAP STATION
5. INSPECTION, MONITOR & DECON AREA
6 WASTE CONTAINER TRANSFER AREA
7 CONVEYOR
8 BRIDGE CRANES
9 AIRLOCK
10. HYDRAULIC DOCK BOARD
11. LEAD GLASS WINDOW (TYPICAL 5 PLACES)



BASEMENT

FIGURE 4-19 PLAN VIEWS OF BASEMENT AND GRADE LEVELS OF MOLTEN GLASS INCINERATION FACILITY

MOLTEN GLASS INCINERATOR PLANS



SECOND FLOOR

1 GLASS FRIT CONVEYOR
3 METAL OBJECTS HOPPER
6 WASTE CONTAINER TRANSFER AREA
9 AIRLOCK
11 LEAD GLASS WINDOW (TYPICAL 7 PLACES)
12 SORTING BIN/CONVEYOR
13 METAL DETECTOR
14 GUILLOTINE SHEAR
15 WASTE CONVEYOR
16 MOLTEN GLASS INCINERATOR
17 SECONDARY COMBUSTION CHAMBER
18 UNDERHUNG CRANE/MANIPUL
19 GANTRY CRANE/MANIPULATOR
20 WASTE ASSAY INSTRUMENTATIO

ORNL DWG 81-4933

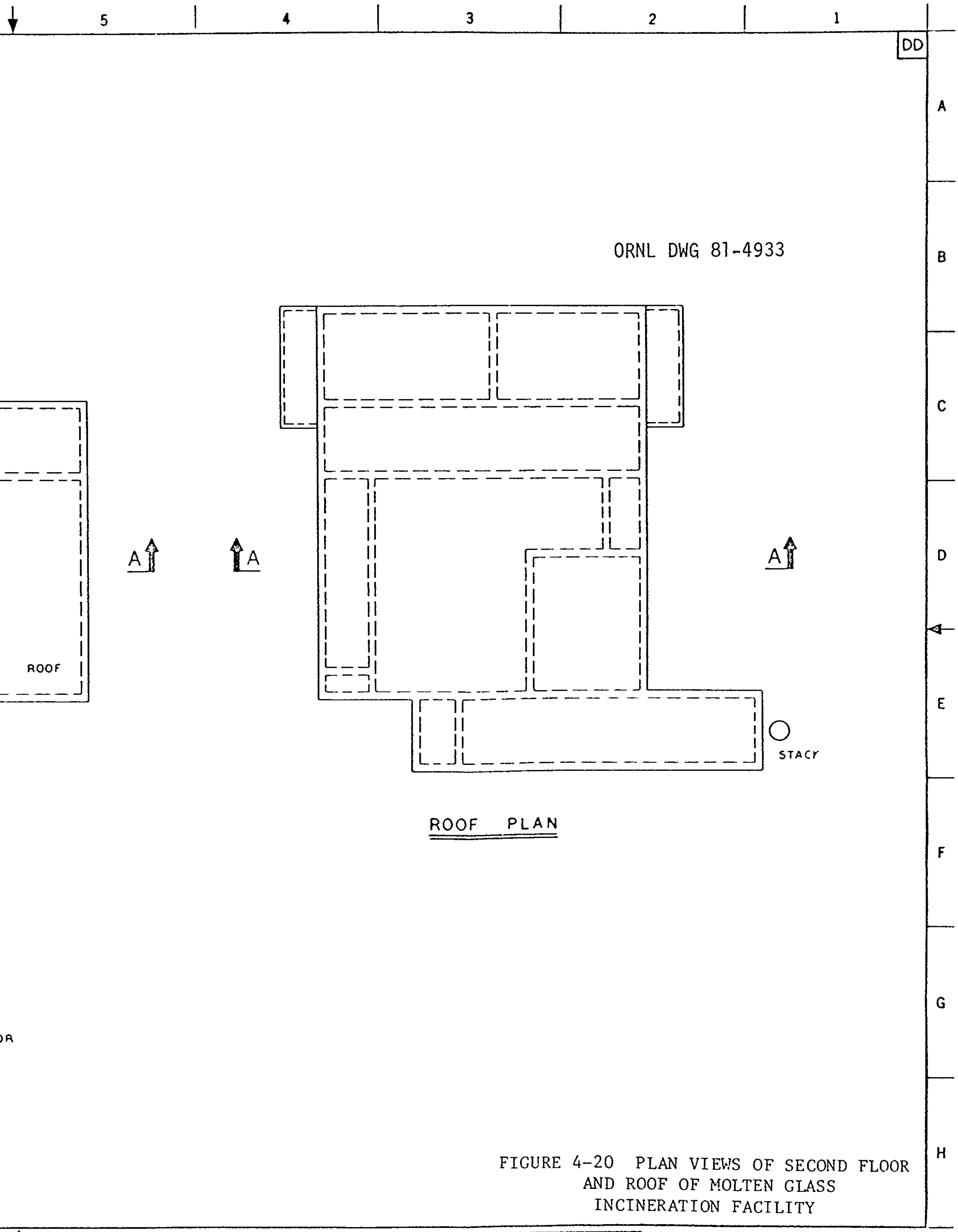
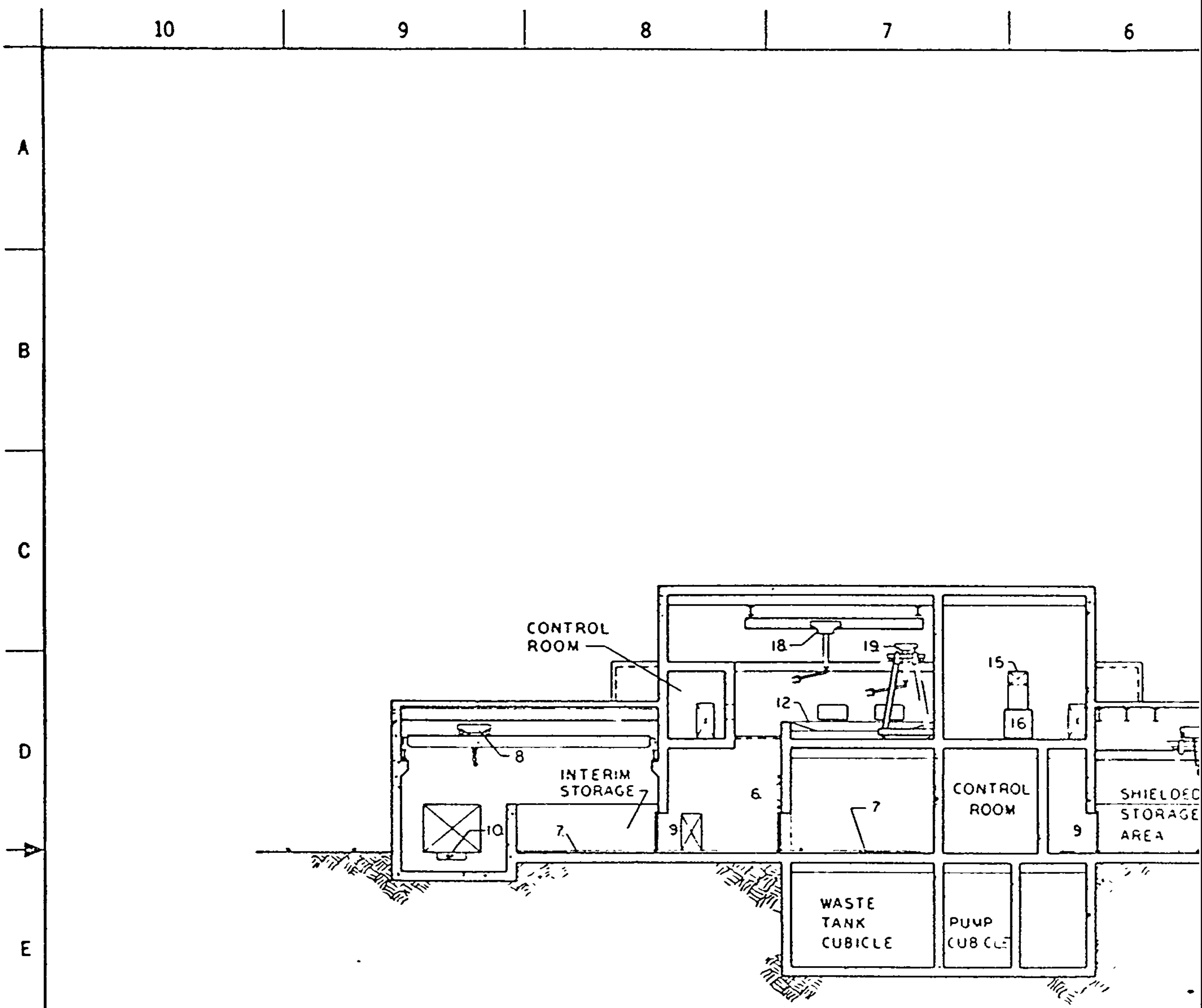


FIGURE 4-20 PLAN VIEWS OF SECOND FLOOR AND ROOF OF MOLTEN GLASS INCINERATION FACILITY

MOLTEN GLASS INCINERATOR PLANS



SECTION A-A

6. WASTE CONTAINER TRANSFER AREA
7. CONVEYOR
8. BRIDGE CRANES
9. AIRLOCK
10. HYDRAULIC DOCK BOARD
11. LEAD GLASS WINDOW (TYPICAL 6 PLACES)
12. SORTING BIN / CONVEYOR
15. WASTE CONVEYOR
16. MOLTEN GLASS INCINERATOR
18. UNDERHUNG CRANE / MANIPULATOR
19. GANTRY CRANE / MANIPULATOR

ORNL DWG 81-4934

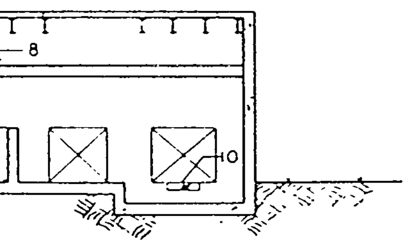
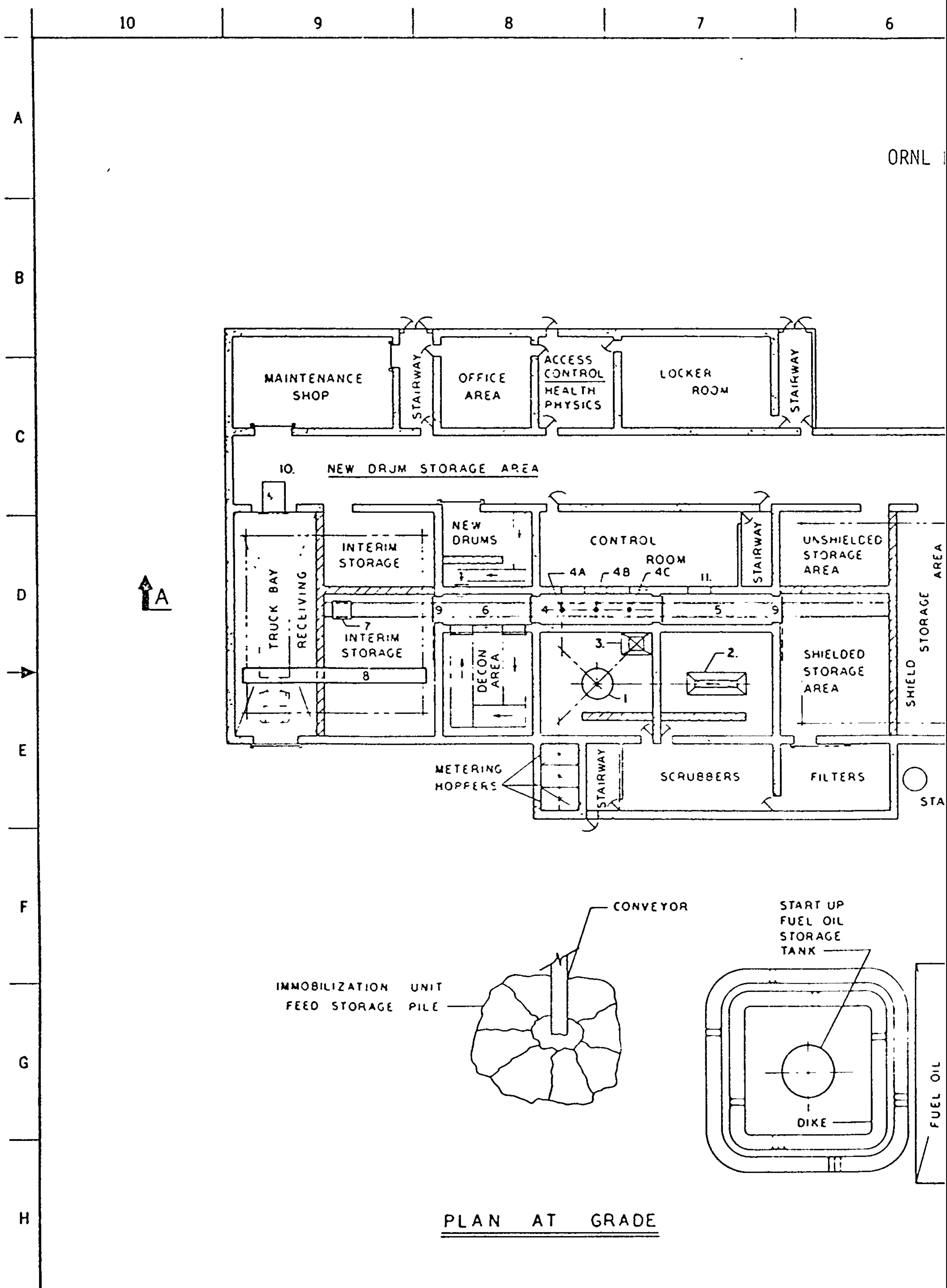


FIGURE 4-21 SECTIONAL VIEW OF MOLTEN GLASS INCINERATION FACILITY

MOLTEN GLASS INCINERATOR SECTION

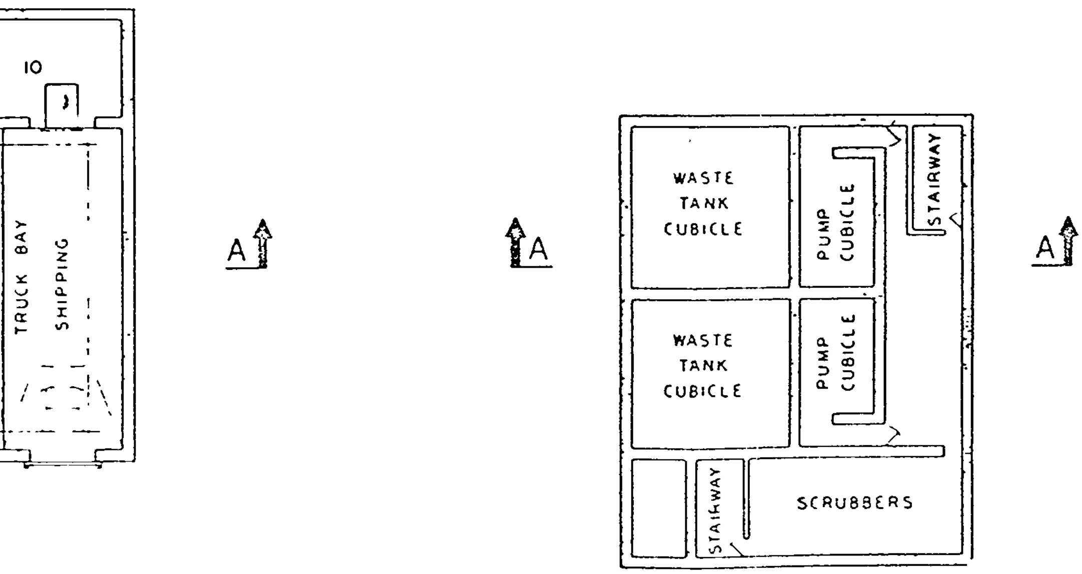
ORNL



PLAN AT GRADE

G 81-4935

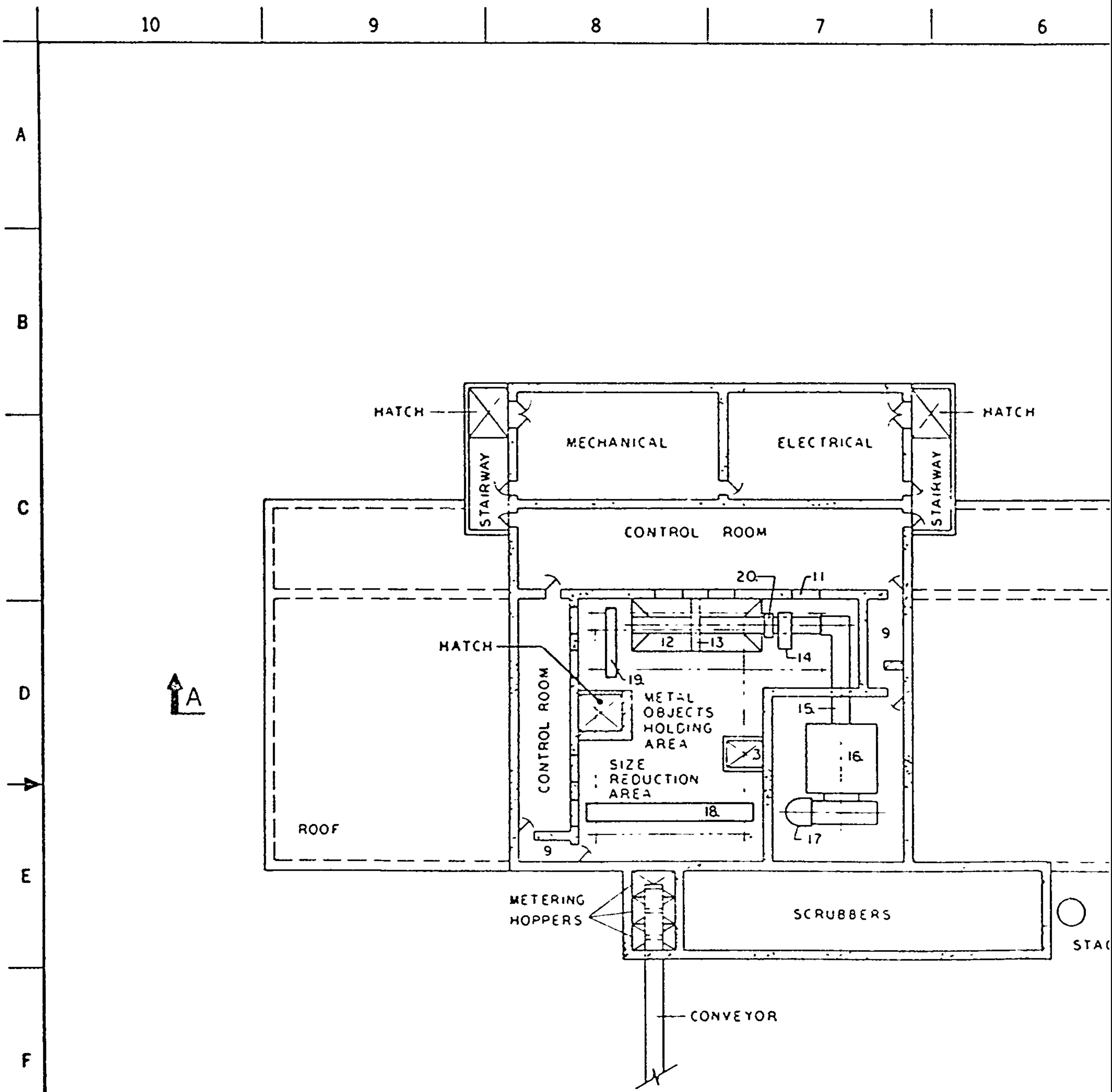
1. SLAG IMMOBILIZATION UNIT
2. ASH HOPPER & CONVEYOR
3. METAL OBJECTS HOPPER & CONVEYOR
4. PACKAGING ALLEY
4A. FILL STATION
4B. Q A STATION
4C. CAP STATION
5. INSPECTION, MONITOR & DECON AREA
6. WASTE CONTAINER TRANSFER AREA
7. TRANSFER CART
8. BRIDGE CRANES
9. AIRLOCK
10. HYDRAULIC DOCK BOARD
11. LEAD GLASS WINDOW (TYPICAL 3 PLACES)



BASEMENT

FIGURE 4-22 PLAN VIEWS OF BASEMENT AND GRADE LEVELS OF ROTARY KILN FACILITY

ROTARY KILN INCINERATOR PLANS



SECOND FLOOR

3. METAL OBJECTS HOPPER
6. WASTE CONTAINER TRANSFER AREA
9 AIRLOCK
11. LEAD GLASS WINDOW (TYPICAL 7 PLACES)
12. SORTING BIN/CONVEYOR
13. METAL DETECTOR
14 GUILLOTINE SHEAR
15. WASTE CONVEYOR
16 ROTARY KILN INCINERATOR
17 SECONDARY COMBUSTION CHAMBER
18 UNDERHUNG CRANE/MANIPUL
19. GANTRY CRANE/MANIPULATOR
20. WASTE ASSAY INSTRUMENTATIO

ORNL DWG 81-4936

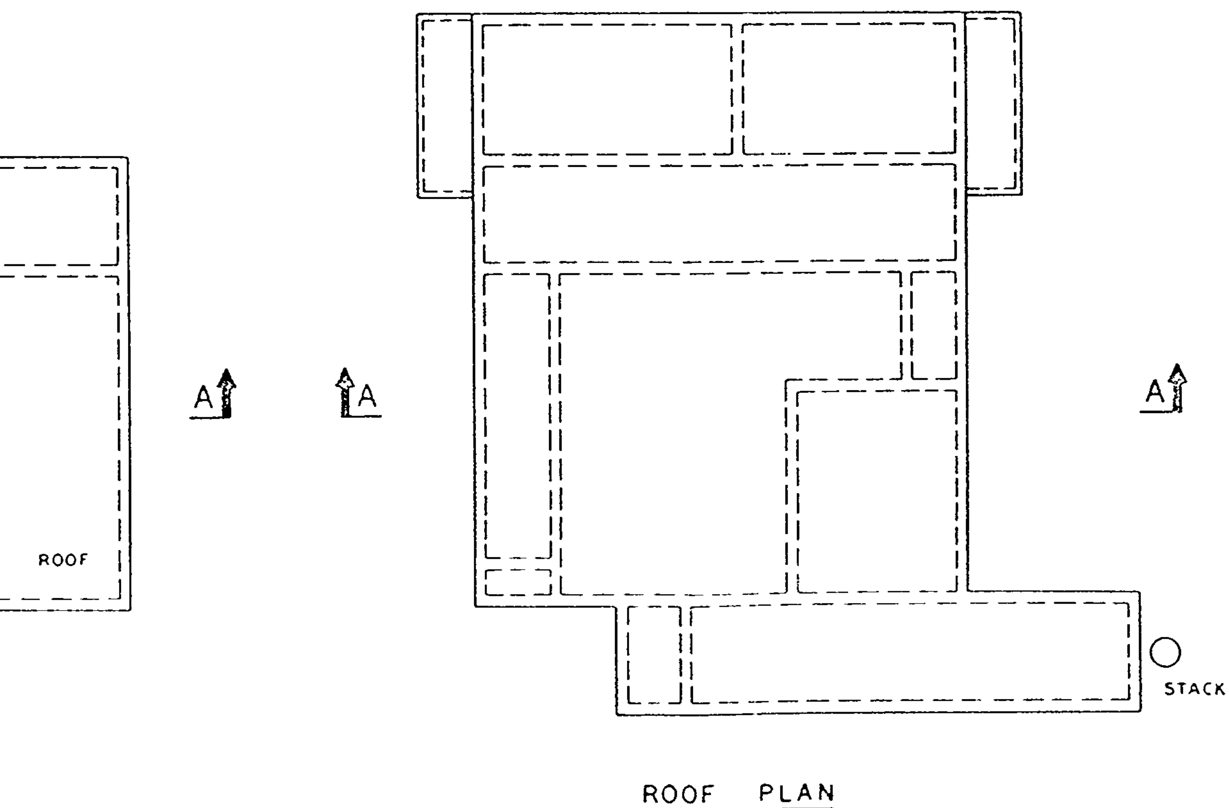
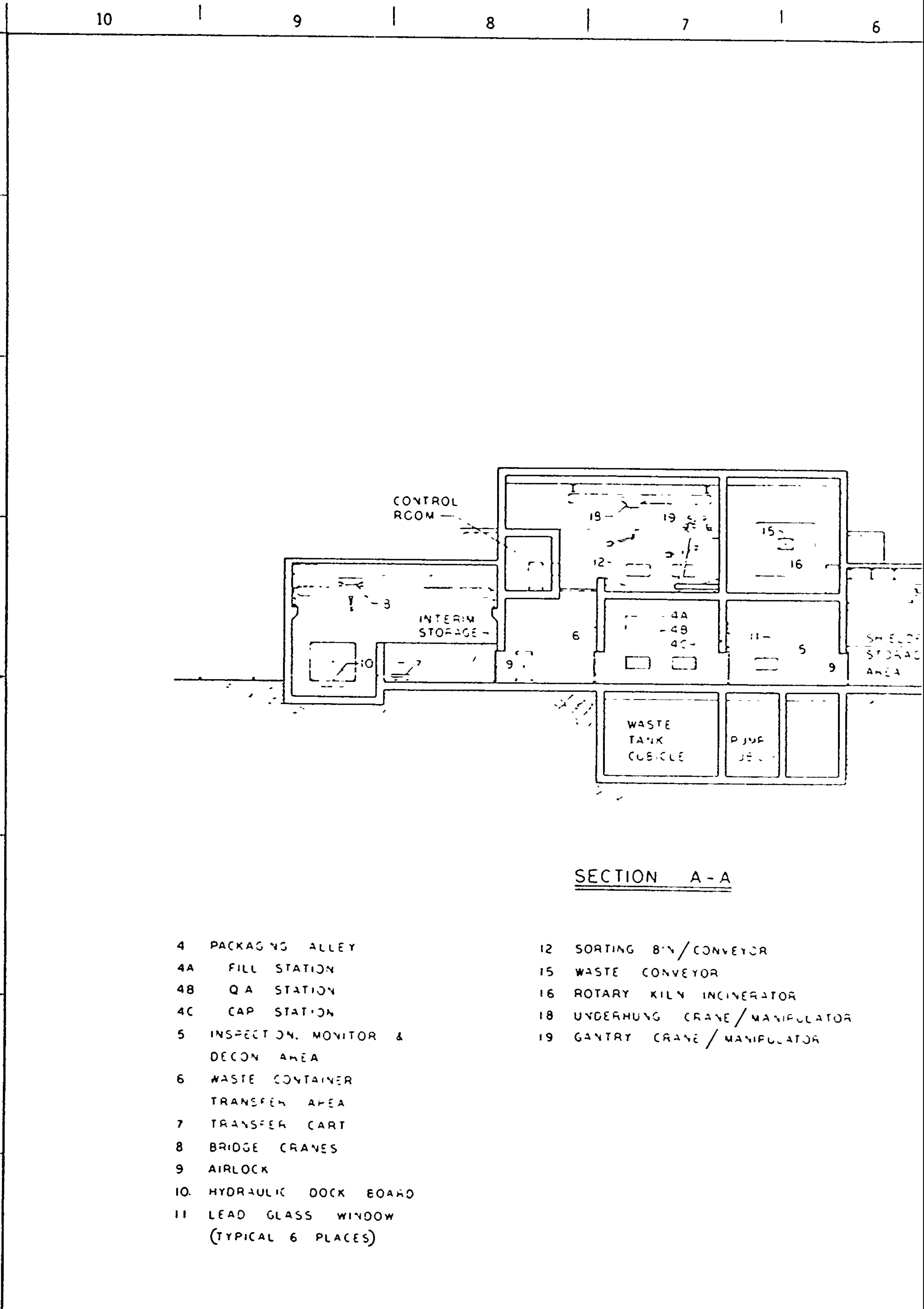


FIGURE 4-23 PLAN VIEWS OF SECOND FLOOR AND ROOF OF ROTARY KILN FACILITY

ROTARY KILN INCINERATOR PLANS



4 PACKAGING ALLEY
4A FILL STATION
4B QA STATION
4C CAP STATION
5 INSPECTION, MONITOR & DECON AREA
6 WASTE CONTAINER TRANSFER AREA
7 TRANSFER CART
8 BRIDGE CRANES
9 AIRLOCK
10. HYDRAULIC DOCK BOARD
11 LEAD GLASS WINDOW (TYPICAL 6 PLACES)
12 SORTING BIN/CONVEYOR
15 WASTE CONVEYOR
16 ROTARY KILN INCINERATOR
18 UNDERHUNG CRANE/MANIPULATOR
19 GANTRY CRANE/MANIPULATOR

ORNL DWG 81-4937

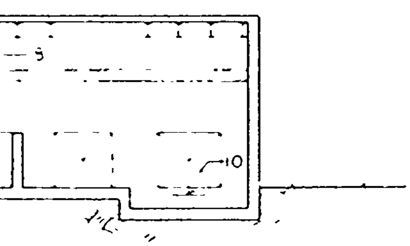


FIGURE 4-24 SECTIONAL VIEW OF ROTARY KILN FACILITY

ROTARY KILN INCINERATOR SECTION

SECTION 5.0

ASSESSMENT OF REQUIREMENTS FOR IMPLEMENTATION OF ALTERNATIVES

SECTION 5.0

ASSESSMENT OF REQUIREMENTS FOR IMPLEMENTATION OF ALTERNATIVES

The primary requirements that must be fulfilled before any of the alternatives identified in Section 4.0 can be implemented are, that the alternative must be technically feasible and it must comply with applicable regulatory requirements. This section presents the considerations associated with these factors.

5.1 TECHNICAL FEASIBILITY

This subsection presents the results of an assessment of factors that affect the technical feasibility of each alternative identified in Section 4.0. Most alternatives would use existing technology and there is little question that the alternatives considered could be implemented, if desired. However, for each alternative, additional information and/or data would be useful in refining the assessments presented in subsequent sections of this report or would be necessary in order to proceed with more detailed design concepts. A discussion of the technical status and data requirements for each of the alternatives is presented in the following subsections. For those alternatives that involve extensions of existing technology, the development work that would be required is also presented.

5.1.1 Alternative 1

Since this alternative is similar to present practices, it could be implemented without any development work. Implementation of this alternative would require:

A. A detailed assessment of the long term integrity of the containers used for storing the waste.

B. The collection of additional information on the geohydrologic characteristics of the storage areas including seasonal water table fluctuations, distribution of fractures in siltstone and sandstone lenses and their effect on groundwater movement, recharge and discharge areas, etc.

5.1.2 Alternative 2

Many of the design features included in this alternative (e.g., the use of clay trench caps) are similar to those used or studied as part of the Low Level Waste Disposal Program. Consequently, no technical difficulty would be expected in implementing this alternative. The additional data that would be desirable to obtain for this alternative includes the two items listed in Subsection 5.1.1 for Alternative 1 and the following:

A. Better definition of the long term moisture exclusion capability properties of the clay caps, liners and underdrain system; and

B. Review and evaluation of passive techniques useful in discouraging intrusion.

5.1.3 Alternatives 3A, 3B, 3C, 3D and 3E

5.1.3.1 General

The discussion of the feasibility of the alternatives identified for Strategy 3 has been grouped together since a number of the considerations involved all of these alternatives. No technical impediments were identified that would prevent the implementation of Alternatives 3A, 3B and 3C. The molten glass incinerator proposed for Alternative 3D and the slag immobilization method proposed for Alternative 3E are in early stages of technical development and their use for these alternatives would not be possible without a substantial development and testing program. Discussion of specific technical feasibility questions for these two alternatives is presented in Subsections 5.1.3.2 and 5.1.3.3, respectively.

Information and data that would be desirable to obtain prior to implementing any of the alternatives for Strategy 3 is as follows:

A. Better definition of the physical and chemical composition, material form and isotopic breakdown of the waste. Limited data exists on the beta-gamma contamination of the wastes stored in concrete casks.

B. Investigation of container design to optimize the container used for each waste form.

C. Determination of optimum size reduction techniques for large items removed from the waste in those alternatives involving sorting.

D. Investigation of the integrity of the existing containers to better determine how many containers would be involved in overpacking and repackaging operations.

E. Determination of the preferred method (including additional development work, if necessary) for assaying the waste for transuranic and fissile content.

5.1.3.2 Development Status of Molten Glass Incinerator Proposed for Alternative 3D

The status of the molten glass incinerator has been recently reviewed in Borduim and Taboas 1980 and in considerable more detail in Bonner, et al. 1980. Although technology for producing high quality glasses using the conductive properties of molten glass is well developed, the use of joule-heated, molten glass furnace for incineration of radioactive waste and immobilization of the resultant residue has only recently begun to be developed. The problem areas and development needs include the following:

A. Better determination of oxidation rates of combustibles and noncombustibles.

B. Determination of the sensitivity of the product glass to variations in the solid waste composition.

C. Investigation of the mixing of waste residues into the melt.

D. Additional study of local variations in melt conductivity.

E. More detailed evaluation of refractory and electrode life.

F. Determination of glass strength and leach resistance for a wide variety of feeds and process conditions.

G. Determination of ultimate deposition sites of volatile radionuclides transported into the off-gas system as a result of combustion taking place above the glass melt.

H. Investigation of methods of controlled cooling of the glass after being cast into drums.

Some of the above data may have already been obtained by Penberthy Electromelt International, Inc. as part of their testing and development program. However, the data made available to date, has been either in the form of marketing brochures or verbal statements. Consequently, prior to a decision to implement Alternative 3D, it would be desirable to initiate a pilot plant program using a complete test loop with all of the off-gas equipment, waste feeding equipment, and appropriate monitoring devices to further define the performance characteristics of the incinerator and obtain the required data. An additional concern is the ability to perform maintenance after the incinerator has become contaminated from processing waste.

5.1.3.3 Development Status of Rotary Kiln and Slag Immobilization Method Proposed for Alternative 3E

Rotary Kiln: The rotary kiln has been used extensively in industrial applications. In addition, a rotary kiln has been installed at the Rocky Flats

Plant to process alpha-contaminated wastes. The incinerator is undergoing startup testing and is scheduled to begin processing waste in July 1981. Consequently, the performance characteristics of the rotary kiln for the proposed application should be well developed before the time an ORNL decision on TRU waste management is required. The primary data needs on the rotary kiln that require resolution, prior to that time, are:

A. Integrity and expected lifetime of the seals on the kiln;

B. Integrity of the refractory or incinerator lining over the expected processing period; and

C. Ability to perform maintenance on the incinerator after it has become contaminated from processing waste.

Slag Immobilization: The development of this immobilization technique has just started (Flinn, et al. 1979). The concept of using molten slag as an immobilizing agent for incinerator residue was an outgrowth of material support studies being performed at INEL as part of the Slagging Pyrolysis Incinerator Project. These studies, which are still in the laboratory research stage, indicate that the waste form that results when the molten slag is cast has the desirable properties of high strength and leach resistance. Although the concept has some similarities to existing technology, much additional development work would be necessary before implementation. The development needs include:

A. Development of equipment suitable for production use.

B. Development of suitable refractory linings for the slag melter.

C. Determination of operating characteristics and slag properties for a wide range of feeds and slag compositions.

D. Determination of expected operational life.

E. More detailed testing of the cast slag to further define its properties.

Additional studies and development work may be necessary as more information on this new immobilization concept becomes available.

5.2 REGULATORY AND LICENSING REQUIREMENTS

Numerous regulatory agencies at the Federal, state and local level would be involved in issuing the permits and approvals that would be necessary to implement most of the waste management alternatives. Consideration of all of these agencies' requirements is beyond the scope of this study. However, the pertinent requirements and guidelines of those Federal agencies whose activities represent a lead or major interface function have been reviewed and are discussed below. The major Federal agencies include the Department of Energy (DOE), Environmental Protection Agency (EPA), Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC).

DOE: DOE offices, field organizations and contractors are required to conduct their operations in accordance with manual chapters originally issued by the Atomic Energy Commission and adopted by DOE upon its formation. The manual chapters that are judged to be the most relevant to the alternatives considered in this study are 0511, 0524, 0529, 0530 and 0531. ORNL routinely conducts its operations in accordance with the requirements of these chapters as directed by DOE.

Chapter 0511, Radioactive Waste Management, requires: a) conduct of operations and disposal and storage of radioactive waste in a manner to assure that present and future radiation exposures will be at the lowest levels technically and economically practicable; b) continuing efforts to develop and use improved technology for reducing radioactive releases; and c) minimization of the extent and degree of contamination of land by waste management activities.

Chapter 0524, Standards for Radiation Protection, provides guidance for radiation protection in normal and accident situations. The chapter sets numerical standards for doses and concentrations of radioactivity that result from DOE and contractor activities.

Chapter 0529, Safety Standards for the Packaging of Fissile and Other Radioactive Materials, establishes packaging standards for shipments of fissile and other radioactive materials not subject to Title 10 of the Code of Federal Regulations (CFR), Part 71.

Chapter 0530, Nuclear Criticality Safety, provides guidance to assure that the handling of fissionable materials is done in a manner that minimizes the likelihood of an accidental criticality.

Chapter 0531, Safety of Nonreactor Nuclear Facilities, contains provisions for assuring that environmental protection and health and safety matters are adequately addressed for nonreactor nuclear facilities and that all identifiable risks are reduced to as low a level as practicable. The chapter includes guidelines for the establishment of Environmental Safety and Health Programs.

EPA: EPA has published criteria in draft form that are generally applicable to all types of radioactive waste (Federal Register 1978 and USEPA 1978). EPA is also developing numerical standards for each waste type, but the standards for high level waste are the only ones expected prior to 1983 (IRG 1979). EPA's proposed criteria: a) define radioactive waste; b) establish, as a fundamental goal for controlling radioactive waste, complete isolation of the waste over its hazardous lifetime (control measures should not rely on institutional functions for longer than 100 years); c) suggest risk assessment as a basis for radiation protection for radioactive wastes; d) provide bases for determining which risks are unacceptable; e) present general guidelines for location of waste disposal sites; and f) suggest inclusion of retrievability and passive methods of communication to future generations as part of waste disposal systems, if use of these additional items provide a net improvement in environmental and public health protection.

DOT: DOT has regulations in force (49 CFR Parts 171-178) which govern packaging and shipping requirements for hazardous material. These regulations apply to shipments by rail or highway in areas where public access is permitted. They do not apply in the restricted areas of DOE sites.

NRC: At present, NRC does not regulate the activities considered in this study. If the recommendations of USNRC 1979 were adopted, all of the alternatives with the exception of Alternative 1 would have to be licensed by the NRC. Definition of the licensing requirements that would be imposed can only be speculated on at this time. Consequently, consideration of potential NRC requirements are not included in the discussions that follow, but it is expected that the overall effect would be to lengthen the implementation schedule and increase the overall cost of the alternatives investigated. Certain alternatives could also be precluded.

5.2.1 Alternative 1

The requirements discussed above that would be expected to have the most effect on this alternative are DOE Manual Chapter 0511 and EPA's radioactive waste criteria. It is doubtful that it could be shown that implementation of this alternative complies with either the provision of 0511 that requires DOE contractors to dispose of radioactive waste in a manner that assures that future radiation exposure will be at the lowest levels technically and economically feasible, or the provision in EPA's criteria that requires justification to show that more complete isolation is impracticable on the basis of technical and social considerations. It is also possible that compliance with the numerical radiation protection standards in Manual Chapter 0524 would become progressively more difficult as the integrity of the containers deteriorated over a period of time. However, none of the guidelines considered would preclude continued use of this alternative during an interim period until a decision is reached on ultimate disposal.

5.2.2 Alternative 2

Implementation of Alternative 2 would also be affected by the guidelines that were discussed above for Alternative 1. The crucial factor in determining if Alternative 2 could comply with these guidelines is whether the proposed improved confinement measures provide adequate isolation of the waste during the period that it is hazardous. This determination would required:
a) extensive geohydrological data for the waste storage area; b) a detailed

evaluation of the long term integrity of the proposed measures; and c) acceptance of the possibility of intrusion at some future time.

In addition to these requirements, a formal safety analysis report would have to be prepared in accordance with Manual Chapter 0531.

5.2.3 Alternatives 3A, 3B, 3C, 3D and 3E

The regulatory factors that most affect implementation of the alternatives for Strategy 3 are the DOE Manual Chapters and DOT regulations affecting packaging and shipment of radioactive waste.

Implementation of Strategy 3 alternatives would require that:

A. Facilities be designed and operations be performed so that radiation exposures and radioactive effluents do not exceed the numerical standards of Manual Chapter 0524, and are at the lowest levels technically and economically feasible;

B. Facility design and operation be in compliance with the provision of Manual Chapter 0531 for the facilities and operations associated with the alternative;

C. An environmental safety and health program be established in accordance with Manual Chapter 0531 for the facilities and operations associated with the alternative; and

D. Packaging and shipment of waste be in compliance with the provisions of Manual Chapter 0529 and 49 CFR Parts 171-178 unless authorized otherwise by DOT.

Of these requirements, Item D is the only one that could pose a significant difficulty in implementing any of the Strategy 3 alternatives. For the type and amount of activity present in much of the ORNL retrievable TRU waste, Manual Chapter 0529 and the DOT regulations specify that Type B packaging be used for shipment. This type of packaging must not only meet the performance standards for normal conditions of transport but must be designed to withstand certain serious accident damage test conditions with limited loss of shielding capability and essentially no loss of containment.

The overpacks and 0.208 cubic meter (55 gallon) drums considered for these alternatives do not meet the requirements for Type B containers. Thus, prior to implementing any of the Strategy 3 alternatives, it would be necessary to obtain an exemption from this requirement by taking credit for the fact that the ATMX 600 railcars provide the equivalent protection of a Type B package (Adcock and McCarthy 1977). In addition, the truck used for transporting the processed waste to the rail loading facility at the Oak Ridge Gaseous Diffusion Plant would have to be designed to similar standards and included in the exemption, since part of the route between the proposed location of the processing facility and the Diffusion Plant is over public roadway.

SECTION 6.0

ASSESSMENT OF NON-RADIOLOGICAL ENVIRONMENTAL IMPACTS

SECTION 6.0

ASSESSMENT OF NON-RADIOLOGICAL ENVIRONMENTAL IMPACTS

The non-radiological environmental impacts of the alternatives discussed in Section 4.0 for managing ORNL's retrievable TRU wastes are, in general, expected to be minor. These impacts are discussed qualitatively in terms of the ORNL site characteristics presented in Section 10, Appendix A. Due to the conceptual nature of the proposed actions and limited data, quantitative evaluations are not possible.

Strategy 1 (leave waste in place as is) would not involve any additional construction. Strategy 2 and 3 alternatives would consist of the construction of facilities to improve waste confinement and to retrieve waste and process for shipment to a Federal repository, respectively.

Potential impacts on the physical, biotic and human environments due to site preparation, construction, operation, decontamination and decommissioning (D&D) of associated facilities are discussed below. Whenever possible, the environmental effects (impacts) are discussed generically. In cases where a generic discussion is inadequate, impacts are discussed in terms of the specific alternative.

6.1 EFFECTS ON PHYSICAL ENVIRONMENT

The impacts of the waste management alternatives on the ORNL physical environment are expected to be minimal. Potential impacts on geology, hydrology and air quality are discussed in the following subsections.

6.1.1 Geology

Construction of facilities will not require major earthmoving. The implementation of standard erosion and sedimentation control procedures will preclude any short term environmental stress on or in proximity to the site. Certain alternatives will require construction of monitoring wells which will neither be employed for consumptive use nor the introduction into ground water of any foreign materials or fluids. The alternative waste management options are not expected to have any adverse effect on the geological environment of the site or region.

6.1.2 Hydrology

The alternative waste management options will not adversely affect the hydrology of the site or region. Small quantities of water required for construction can be obtained from existing ORNL supplies. Water required for the construction, operation and D&D activities associated with any alternative will be treated prior to discharge to any streams. Runoff from the construction site(s) into nearby waters will not be contaminated and will be controlled to minimize impacts. Required facilities will be constructed to conform with existing drainage patterns and contours.

6.1.3 Air Quality

Air quality impacts can occur as a result of the construction and operation of facilities associated with the proposed actions. These impacts will be minimized by the use of proper construction procedures and emission control equipment to maintain applicable air quality standards. Accordingly, the effect of the alternatives upon the quality of the air is expected to be minor.

The major air quality impacts associated with the construction of required facilities or improvements would result from construction vehicle emissions and equipment exhaust and from generation of dust. Although some adverse air quality impacts are likely due to this construction, strict adherence to Federal and state standards will be maintained. Mitigative measures that could be used to achieve compliance include: a) application of dust palliatives other than oil; b) limited disturbance of vegetative cover; and c) use of erosion control and restorative techniques to minimize wind generated dust.

Because of the isolation of the ORNL site and the localized nature of the effects, no adverse impacts to the general public are expected. Localized adverse air quality would affect the construction workers and nearby laboratory personnel. However, this would cease with completion of construction and restoration of vegetative cover.

Depending upon the waste management alternative, operation and D&D activities would increase the non-radiological airborne effluent at ORNL. Leaving the waste in place, as is (Alternative 1) or improving confinement (Alternative 2) would result in little or no operational impacts. Alternatives 3A, 3B, 3C, 3D and 3E which involve retrieval, processing and shipment will have the largest impact. The primary effects would be from stack emission associated with the incineration alternatives (Alternatives 3D and 3E) and vehicular exhaust from the retrieval and shipping operations. Stack emissions from the incinerator alternatives will be controlled by facility-equipment and operating/monitoring procedures to comply with applicable air quality standards. Other emissions would represent a minor increase over the current discharges from existing facilities and vehicles in use at ORNL.

6.2 EFFECTS ON BIOTIC ENVIRONMENT

Plant and animal communities which now inhabit the site will be displaced by construction of facilities associated with the various alternatives; however, adverse impacts on neighboring biota, due to construction operation or D&D activities, are expected to be minimal.

6.2.1 Terrestrial

Construction related effects on the terrestrial environment would include potential impacts on vegetation and wildlife. The primary effect is the removal of vegetative cover for facility construction. Some of the disturbed areas could be revegetated; however, the total affected area could not be restored to preexisting conditions until after D&D is completed.

Additional ORNL acreage could be disturbed as a result of extraction of construction materials such as gravel, clay, sand, etc. These activities could be carefully planned to minimize or avoid adverse affects on existing flora and fauna. After material needs have been satisfied, these sites would be restored.

Removal of vegetative cover would increase the potential for erosion by runoff and wind effects. It also reduces habitat and cover for wildlife. Erosion can and would be minimized by standard control techniques, but certain habitat areas would be lost for the duration of the proposed actions.

Areas that would be affected by the proposed alternatives are in order of tens of acres. Short and long range loss of the vegetative cover and wildlife habitats for this size area would represent a minor impact due to the availability of similar habitats on the ORNL site.

Short term impacts to wildlife would occur as a result of construction activity and noise. Heavy machinery operation would have localized effects on some animal species resulting in their migration away from the source. Nesting, breeding and foraging areas could also be affected; however, most species would return when construction and restoration are complete.

Adverse impacts on the terrestrial environment due to operation and D&D efforts of the proposed alternatives is expected to be minimal. Sources of these impacts depend upon the alternative to be implemented and could include: a) increased air pollution, b) contact with hazardous components of the wastes by plant roots or burrowing animals and c) wildlife kills along roadways. Although these effects cannot be eliminated, proper design and operating procedure will be utilized to reduce their severity. Coordination with the Department of Environmental Management at ORNL will be utilized to ensure no adverse impacts to the Ecology Study Areas at the laboratory.

6.2.2 Aquatic

The impact to the aquatic environment resulting from implementation of any of the alternative management options is expected to be minor.

During construction, runoff, erosion and sedimentation effects will be controlled by proper grading and the use of sedimentation ponds. Other water quality impacts from minor oil spills, etc. will be minimized by the use of good construction practice. Applicable Federal and state water quality and effluent guidelines would be applied to the management of waste waters generated from construction activities. Sanitary wastes will be handled by the use of portable units or will be treated before discharge to the environment.

During operation and D&D efforts, there will be no direct discharges to surface streams. All liquid wastes will be treated before discharge to comply with applicable regulations. Thus, minimal effect on the water quality and aquatic ecosystem is anticipated.

6.2.3 Special Considerations

The proposed location for conducting the alternative management schemes does not appear to contain any ecological features, such as a strategic position in or near a migration corridor, that would make it unique within the ORNL region. The location and immediately adjacent areas do not contain natural landmarks or areas and do not appear to contain endangered species, species whose status is being determined, endemic species, disjunct populations or critical habitats. Rare and endangered plants and animals (see Section 10.0, Appendix A) have been found on the ORNL reservation and suitable habitats occur for numerous other unique species. A detailed survey is required, prior to the implementation of any of the proposed alternatives, to assure that species of special ecological interest are not adversely affected.

6.3 EFFECTS ON HUMAN ENVIRONMENT

The effects of implementing any of the alternative waste management schemes on the human environment is also expected to be minor. Potential impacts on local community, land use, transportation, archaeological/historical sites and aesthetics are discussed below.

6.3.1 Local Community

The effect on the local community due to the construction, operation and D&D activities will vary depending upon the alternative selected for implementation. In general, the effects are expected to be minor, but positive.

Much of the construction force will consist of existing ORNL personnel and local contract labor. Permanent relocation of any new workers and their families is not expected due to the relatively short duration of the construction effort. Most of the routine construction materials will be obtained from the local area.

Operation and D&D efforts will occur over a two to five year period. During this period increased employment due to this effort is not expected since most of the positions could be filled by current ORNL staff.

The total construction and operating personnel requirements are small compared to the existing DOE work force and area population. Consequently, little, if any, effect on the local communities can be expected.

6.3.2 Land Use

The ORNL reservation is committed for the purpose of energy research and development and related program activities. Waste management is considered a related activity and consistent with this established objective. Development of any of the alternatives would be compatible with existing land uses nearby. Alternatives 1 (leave as is) and 2 (improve confinement) would be a continuation of current practice and use; Strategy 3 alternative would not alter this use significantly. The proposed location for the processing facilities is on an undeveloped parcel of land adjacent to the Hydrofracture Facility, now under construction.

6.3.3 Transportation

Impacts on the transportation system serving the Oak Ridge area resulting from implementing any of the alternatives is expected to be insignificant.

No effect on highway traffic volumes can be expected since the majority of the required labor can be supplied locally and is small relative to the number of existing laboratory personnel.

During the construction phase, rail service would be used to transport heavy equipment to the rail loading facility at ORNL. The same facility would be used during the operational and D&D phases of some of the alternatives, to transport repackaged/processed waste offsite. Because of the relatively small amount of rail service required to implement any of the alternatives, no disruption of rail traffic is anticipated.

6.3.4 Human Interest

The implementation of any of the waste management alternatives is not expected to have an impact on any natural or state historic sites, designated archaeological areas, national landmarks, or wild and scenic rivers. Furthermore, no significant impacts are expected on any parks, recreational areas or institutions because of their distance.

An archaeological survey of the Oak Ridge reservation was performed in 1974 (see Section 10.0, Appendix A). Sites of aboriginal occupation that might affect future activities were located and evaluated.

Prior to any required construction, measures for assuring protection of antiquities and historic sites, as required by Federal and state regulations, will be accomplished. This would include site reconnaissance and possibly excavation and salvage operations, as required.

6.3.5 Aesthetics

Construction of the facilities for managing ORNL retrievable TRU wastes would not significantly detract from the existing aesthetic quality. In general, topographic barriers and limited road access would shield these facilities from general view. Visual impact would also be minimized by considering aesthetic qualities in any facility design.

SECTION 7.0

ASSESSMENT OF RADIOLOGICAL IMPACTS AND RISKS

SECTION 7.0
ASSESSMENT OF RADIOLOGICAL IMPACTS AND RISKS

This section presents the results of an assessment of radiological impacts and risks associated with each alternative. The assessment has been limited to determination of the consequences and risks to members of the public as the result of radioactive releases. Assessment of occupational radiation exposures and of non-radiological risks has been deferred to a later phase in the selection of an alternative for management of ORNL's retrievable TRU waste for the following reasons:

A. The data necessary to make these assessments is very limited at present (data is in particular lacking on the activity and isotopic breakdown of the beta-gamma contaminants in the TRU waste);

B. Neither assessment appears to be a major factor in any initial decisions about the waste management alternatives.

The assessment for risks and radiological impacts presented herein considers radioactive releases that could occur in one of the following ways:

A. As a routine release, i.e., a release from the normal operation of the facility or from the normal functions performed during decontamination and decommissioning (D&D) of any interim facilities associated with the alternative;

B. As a release from a postulated accident during waste retrieval, waste processing; or

C. As a result of external actions such as natural events, airplane crash, intrusion, etc.

The assessment provides a quantitative method of comparing the various alternatives in terms of the potential hazards associated with the transuranic contaminants in the waste.

Risk provides a measure of both the likelihood of an event and the consequences resulting from that event. In this report, the consequence of interest is the dose resulting from a particular event that leads to a release of radioactivity. Risk is defined as the product of the frequency of a given event in terms of the expected number of events per year times the magnitude of the consequences of the event expressed in terms of a dose commitment to an individual or a group of individuals. With this definition, it is apparent that low probability-high consequence events can have the same risk as high probability-low consequence events. This makes it possible to more quantitatively determine if the costs or benefits of a particular risk reduction technique (a measure that either mitigates the consequences of a given event or reduces the expected frequency of the event) are reasonable.

Risks extend over different periods of time for different alternatives. Time-dependent risks are compared by integrating them over the time period that the risk is incurred. Time-integrated risks take into account: 1) radioactive decay and other time-dependent factors that affect the amount of radioactivity available for release; 2) changes in population (if time-integrated risks are being determined for a particular population group); and 3) the period of time that the particular alternative is susceptible to the risk being considered.

7.1 GUIDELINES AND GENERAL ASSUMPTIONS USED IN ASSESSMENT OF RISKS

The risk assessment was structured to provide comparative information on the alternatives discussed in Section 4.0. The numerical risks, dose commitments and calculated health effects reported should not be taken in the context of absolute values. The guidelines, bases and assumptions that are generally applicable to the risk assessment are given below. Specific assumptions are described in the discussion of the risk assessment performed for the given alternative.

Guidelines and general assumptions:

A. The date when each alternative is assumed to commence, if chosen for implementation, is 1995. This was done in order to have the assessment of each alternative based on a common starting date.

B. In assessing alternatives in which human action is required, such action is assumed to end after 100 years. The basis for this assumption is EPA's Proposed Criterion No. 2 for radioactive waste (Federal Register 1978) which specifies that controls that rely on institutional functions should not be relied upon for longer than 100 years to provide isolation of radioactive waste.

C. Only events that might occur in a time period of the order of 1,000 years are considered. This choice is based primarily on EPA's Proposed Criterion No. 3 for radioactive waste, which indicates that risk assessments should consider effects for 1,000 years or any shorter period of hazard persistence.

D. The events considered in the risk assessment represent a reasonable spectrum of the type of events that could lead to a release of activity. The risks of the events considered can be used to determine upper bounds for many initiating events. However, combinations of events (e.g., a facility fire concurrent with an earthquake or tornado) and consideration of all possible "what if" situations is beyond the scope of this study.

E. The risk assessment is not organized in a modular fashion as were the assessments in two other similar studies (USDOE 1979 a and b). In general, only the scenario for a particular event that is the most limiting (i.e., contributed the most significantly to the risk associated with the event) is considered. The primary reason for this is the relatively small number of alternatives considered in the study limited the value of organizing the risk assessment by modules.

F. For alternatives that involve shipment of waste to a Federal repository, assessment of the risks incurred after the waste arrives at the repository are beyond the scope of this study.

7.2 METHODOLOGY

7.2.1 Event Frequencies

The scenarios included in the risk assessment include the following types of events:

- ROUTINE RELEASES
- NATURAL EVENTS
  - Earthquake
  - Flooding
  - Tornadoes
  - Meteorite
  - Erosion
- PROCESS INCIDENTS
  - Nuclear Excursion
  - Explosion
  - Fire
  - Filter Failure
  - Waste Handling Accident
- TRANSPORTATION
  - Routine Exposures
  - Accidents
- AIRPLANE CRASH
- INTRUSION

Sabotage is also a possible scenario to be considered in performing the risk assessment. Because of the sensitive nature of the event and the unavailability of data for performing an assessment similar to those performed for the scenarios listed above, it is not included in the discussions or tabulations in the remainder of this section.

For a given alternative, the applicable events from the list given above were selected. Event frequencies were determined from ORNL data and experience when available. For some events, event frequencies were based on data from the Idaho National Engineering Laboratory and the Savannah River Plant (USDOE 1979 a and b). For those cases where data on event frequency was unavailable or could not be reasonably estimated, only dose commitments as a result of the event were calculated.

7.2.2 Activity Release

The waste inventories presented in Subsection 3.3 were utilized in determining the amount of activity available for release as the result of a particular event. A release fraction was determined for most events based on the fraction of the waste inventory affected by the event and on the assumptions made about the event. The release fraction was assumed to be the same for all isotopes considered. Although for most events, the differences in physical and chemical properties would result in different release fractions for each isotope, insufficient data is available to make a reasonable determination of these differences.

7.2.3 Dose Commitments

For each activity release, the applicable pathways to man at the time of the release were determined. For most releases, inhalation of activity in the plume is the primary pathway.

The dose calculations utilize the values given in Hoenes and Soldat 1977 for adult 50 year whole body dose commitment factors. The dose commitment factors given in Hoenes and Soldat 1977 are, in general, applicable only for chronic intake over a period of a year. However, for the isotopes considered, the values used are almost identical to those given in an unpublished tabulation of 50 year dose commitment for acute intake obtained from Soldat. Dose commitments to organs other than the whole body are not explicitly calculated but are included in the determination of health effects discussed in Subsection 7.2.5.

Dose commitments were determined for a hypothetical individual located at the point of maximum probable exposure outside the restricted area. For releases that occur over a period of time (e.g., routine releases), only unrestricted areas where individuals could reside were considered. Dose commitments were also determined for the maximum population sector. The maximum sector was determined by considering both the population of the sector and the atmosphere dilution factors for the sector.

The atmospheric dilution factors (χ/Q) used in the calculations were taken from the meteorological data measured at ORNL and tabulated in the Preliminary Safety Analysis Report (PSAR) for the Clinch River Breeder Reactor. The atmospheric dilution factors used for routine releases are based on annual average data. The atmospheric dilution factors used for releases of a non-routine nature are based on the zero to eight hour χ/Q accident meteorology values given in the Clinch River PSAR. These are based on conditions that were not exceeded 95 percent of the time during the period when the meteorological measurements were made. The χ/Q values used do not consider removal processes such as deposition and thus are considered conservative.

The population data given in the Clinch River PSAR were used in the determination of population dose commitments. Based on these data and on the meteorological data previously discussed, the maximum sector is the ENE sector. Population dose commitments were determined out to a distance of 80 kilometers (50 miles), the distance to which data is readily available. The age distribution of the population was not taken into account in determining population dose commitments. This is also a conservative assumption for the pathways considered.

7.2.4 Risks

The event frequencies discussed in Subsection 7.2.1 and the dose commitments discussed in the previous subsection were used to calculate maximum individual risks and maximum population risks. Time integration of maximum individual risks would result in averaging risks over many different "maximum individuals" and would thus not provide any additional useful information. Population risks, by the manner in which they are calculated, provide information on average risk. Thus, time-integrated population risks do provide useful information. They were calculated by integrating the maximum population risks over the time period that the risks are incurred. Population growth was taken into account in the following manner: 1) the population of the maximum sector in the year 1995 was interpolated from population projections given in the Clinch River PSAR; 2) for the 100 years after 1995, the population of the maximum sector was assumed to grow at a rate of one percent per year; and 3) after 2095, the population of the maximum sector was assumed to remain stable. The one percent growth approximates the growth experienced by the most significant fraction of the population in the maximum sector during the 1950-1970 period. The assumptions that the growth would continue for an additional 100 years and that the population would remain relatively constant thereafter is somewhat arbitrary but are judged to represent reasonable population growth factors for assessing the time-integrated risks.

7.2.5 Health Effects

The time-integrated population risks were used in estimating potential health effects in terms of cancer fatalities. Using the data on cancer fatalities per 10^6 man-rem given in USEPA 1974 and the dose commitment factors by isotope for the whole body, bone, lung, liver and kidney, fatalities per whole body dose in rem were determined as shown in Table 7-1 for the inhalation pathway.

7.3 ASSESSMENT OF RISKS FOR ALTERNATIVE 1

As described in Subsection 4.1, this alternative consists of leaving the wastes in place without providing any additional protective measures. Security, monitoring, and maintenance would continue for the assumed 100 year institutional control period. At the end of this period, these measures would cease and only passive barriers would be available to provide waste isolation.

The events considered applicable for this alternative are as follows:

- ROUTINE RELEASES
- NATURAL EVENTS
  - Earthquake
  - Flooding
  - Tornadoes
  - Meteorite
  - Erosion
- PROCESS INCIDENTS
  - Fire in Waste Containers
  - Nuclear Excursion
- AIRPLANE CRASH
- INTRUSION

7.3.1 Routine Releases

Routine release of activity has not been observed in the 10 years since ORNL's TRU waste began to be stored retrievably. Because surveillance and maintenance would be performed during an assumed 100 year period of institutional control, routine releases, if they occurred during this period, could be detected and corrective action taken. Consequently, dose commitments are expected to be negligible during the 100 year surveillance period.

Dose commitments beyond the 100 year period are calculated using the following conservative assumptions:

A. The buried casks which can only be inspected indirectly deteriorate over the 100 year control period and activity from the waste begins to be leached at a rate of one percent per year into the surrounding soil (actual leach rates for the waste is expected to be substantially less);

B. The stored casks and drums which are directly inspected and maintained during the control period deteriorate after the end of the control period and activity begins to be leached at the end of 500 years at a rate of one percent per year into the surrounding soil;

C. Transport of the leachate would be governed by soil and groundwater properties. The soil in the waste storage area is Conasauga shale. Laboratory measurements on this shale indicate that it has a high ion exchange capacity and is relatively impermeable. However, field observations of Conasauga shale at other locations on the Oak Ridge Reservation indicate the presence of highly permeable siltstone and sandstone lenses, extensive fracturing and a relatively high groundwater velocity (Webster 1976, Butz, et al. 1980). Although the geohydrological conditions at the TRU waste storage area are not very well known, it is possible that conditions exist which would provide very little retardation of the leachate in comparison to the period during which it would remain hazardous. Consequently, for conservatism, no credit was taken for retardation or for dilution in uncontaminated groundwater;

D. The contaminated water is assumed to discharge into one of the numerous surface streams in the area and eventually reach the Clinch River;

E. Dose commitments to the maximum individual are calculated assuming that this individual drinks one liter per day of contaminated water from the surface stream. The average flow of this stream is assumed to be 0.0283 cubic meters per second (one cubic foot per second); one CFS;

F. Population dose commitments are calculated assuming the contaminated water is diluted in the average flow of the Clinch River and an assumed population of 100,000 drinks one liter per day from this portion of the Clinch River of the contaminated water. (The population in the vicinity of the waste storage area that currently uses the Clinch River as a source of drinking water is considerably less than 100,000.)

The resulting dose commitments, risks and health effects for routine releases resulting from Alterntive 1 are presented in Table 7-2.

7.3.2 Natural Events

Natural events considered for this alternative include earthquakes, floods, high winds, meteorite strikes and erosion. Each event is assessed as to its potential for release of activity. For those events judged to have the potential for activity release, dose commitments, risks and health effects are calculated as discussed below. There are a number of other natural events such as glaciation, climate change, river course alternation, etc. which were not considered because they were judged to be very unlikely to occur during the assumed assessment period.

Earthquakes: A major earthquake centered near the Oak Ridge area would be necessary in order to cause a release of activity of any significance. As discussed in more detail in Section 10.0, Appendix A, the Oak Ridge reservation is an area of only moderate seismic activity. In the last 165 years, there have been five earthquakes that produced a Modified Mercalli intensity (MM) V to VI within the vicinity of Oak Ridge. Earthquakes of this intensity are not severe. During the same time interval, no earthquakes of intensity MM VII or higher were reported. It is highly improbable that a shock of major intensity will occur in the Oak Ridge area for several thousand years to come (USAEC 1962). Forces from more seismically active areas will probably be dissipated by distance. Consequently, no release of activity is expected to occur as a result of an earthquake during the 1,000 year period for which risks are being assessed.

Flooding: Based on Lesesne 1979, the maximum probable flood elevation for the area in which the waste storage facilities are located is 241 meters (790.5 feet). This is significantly below the elevation at which the TRU storage facilities are located. Consequently, no release of activity from the stored TRU waste as a result of flooding is expected.

High Winds: The Oak Ridge Reservation is located in an area infrequently subjected to tornadoes and has one of the lowest probabilities of tornado occurrence in the State of Tennessee. For the one degree square of latitude and longitude in which the TRU waste storage areas are located, the annual tornado frequency is 0.5. The probability that a tornado will strike any point in this square is 3.65×10^{-5} per year (Boyle, et al. 1978).

The only portion of the stored TRU waste expected to be vulnerable to a tornado are the drums stored in Building 7826. Because of the design and spacing of the roof framing members for this building, free passage of a drum through the roof framing is considered to be extremely unlikely. The only credible occurrence that could cause the release of activity would be penetration of the roof of Building 7826 by a tornado-generated missile with sufficient kinetic energy to puncture one or more drums. The dose from such a release would be very small because of the dispersion caused by the tornado and because of the small number of drums involved.

The effects of other high winds such as from a hurricane would be substantially less than that of a tornado.

Meteorite: The impact of a large meteorite on any of the TRU waste storage facilities would be sufficient to cause a significant fraction of the waste to vaporize. The limiting case for this event would be the impact of the meteorite on the drum storage area. Consequences of this event are calculated assuming that all of the waste in the drum storage area vaporizes and one percent of it is respirable. A frequency of 10^{-10} per year was used based on USDOE 1979 a. The results of the calculation are presented in Table 7-2.

Erosion: During the assumed 1,000 year assessment period, neither the waste storage buildings or the burial trenches are expected to erode or deteriorate to the point that surface transport of the waste would occur.

7.3.3 Process Incidents

The process incidents that are considered applicable for the assessment of risks for this alternative are a fire and a nuclear excursion. Consideration of these incidents is discussed below.

Fire: Fire is not expected to occur in the waste storage containers as long as they maintain their integrity since the combustible material has access to very little air to support combustion. The limiting case for this event is based on failure of one of the drums immediately after the assumed 100 year institutional control period and spontaneous combustion of its contents. For conservatism, all of the drums in one layer of the storage cell in which the failed drum is located are assumed to be affected by the fire. The release from this event is calculated assuming that all of the combustible material in the affected drums burns and that all of the activity associated with the burned material becomes airborne. Of the activity released, it is assumed that one percent is respirable (Mishima 1974 and Mishima and Schwendiman 1973). The frequency of spontaneous combustion is assumed to be 10^{-2} per year (USDOE 1979 a and b). The calculated risk and consequences of this event are given in Table 7-2.

Nuclear Excursion: The amount of fissile material allowed in a given storage container is limited administratively to assure that an infinite array of storage containers would be safety subcritical. In any case, where the specified limits must be exceeded, the problem is submitted to the ORNL Criticality Committee for review and recommendations. Although the waste containers may deteriorate over the period for which risks are being assessed, changes in the waste configuration to a point where it approaches a critical array is not considered possible.

7.3.4 Airplane Crash

McGhee-Tyson Airport, which is located over 40 kilometers from the ORNL TRU waste storage area, is the only airport in the region used by aircraft large enough to significantly damage the TRU waste storage facilities. Based on information provided in the Clinch River Breeder Reactor PSAR, the nearest flight path into McGhee-Tyson is over 15 kilometers away and the nearest holding pattern is more than 40 kilometers from the TRU waste storage areas. Using the methodology of Wall 1974, a probability of 1.2×10^{-6} per square kilometer per year was calculated for an aircraft crash with a high enough impact to cause a significant release of activity. The limiting case would be a crash into the drum storage facility in 1995. It is assumed that the crash and ensuing fire causes all of the combustible material to burn. One percent of the material that becomes airborne is assumed to be respirable (Mishima 1974). The resulting dose commitments and risks are presented in Table 7-2.

7.3.5 Intrusion

After the 100 year institutional control period, inadvertent or even intentional contact with the waste is possible. The scenario considered for this event is inhalation of dust by a reclaimer* searching for valuables. To assess the risk of this event, it is assumed that an individual spends 100 hours retrieving and examining waste material. As a result of these activities, a dust cloud of 1 milligram per cubic meter of waste material develops (Rogers 1979). The reclaimer breathes this dust throughout the 100 hours at the breathing rate of an active man (1.25 cubic meter per hour).

Population doses are determined assuming that the dust cloud travels in the direction of the maximum population sector with accident meteorological conditions prevailing. The calculated maximum individual and whole body dose commitments are given in Table 7-2. Risks are not calculated for this event

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* The reclaimer would also be exposed to direct radiation during his reclamation activities but there is insufficient data available on dose rates or on complete isotopic inventories of each waste package to assess direct exposures. Exposure of the general population by direct radiation from the waste package is negligible.

because of the difficulty in estimating event frequency with any degree of certainty.

Other intrusion events that were considered include:

A. animal burrowing,
B. penetration of deep rooted species into the waste,
C. farming,
D. complete redevelopment of the site for an alternate use such as housing development, etc.

The consequences of the first three events were estimated on an order of magnitude basis and found to be less than those for the event considered. The last event would result in more severe consequences but was judged to be very improbable and thus would be less limiting in terms of risk than the event considered.

7.4 ASSESSMENT OF RISKS FOR ALTERNATIVE 2

Alternative 2 includes security and surveillance features of Alternative 1 plus a number of measures designed to improve the degree of confinement of the waste. These measures are described in Subsection 4.2 and include: a) the addition of clay liners between and around each layer of waste containers in each storage facility to retard water movement into or out of the waste; b) the addition of a double clay cap with rip rap protection over each facility to retard the infiltration of precipitation; c) the addition of a gravity underdrain system to passively lower the water table in the vicinity of each facility; d) movement of the buried casks to a storage facility similar to Building 7855 to assure that they remain above seasonal fluctuations of the water table; and e) emplacement of soil lysimeters and additional monitoring wells to provide additional information on the geohydrology of the waste storage area. Construction of the clay linings, caps, etc. is assumed to be accomplished over a one year period. Surveillance and security measures would continue throughout the assumed 100 year institutional control period.

7.4.1 Routine Releases

The protective measures included in the improved confinement alternative are expected to significantly reduce the potential of routine releases. Risk to the public is expected to be negligible during the 1,000 year period for which risks are being assessed unless the improvements deteriorate significantly over this period.

7.4.2 Natural Events

Of the natural events considered in Subsection 7.3.1 for Alternative 1, only the risk associated with a tornado would be expected to be different. Since the waste containers are removed one storage bay at a time in order to construct the clay liners, the containers could be exposed to the effects of a tornado during this time. After the improved confinement measures have been completed, the effects of a tornado on the waste would be expected to be minimal. The limiting scenario for this event is calculated assuming that all of the drums contained in one storage bay are breached by the tornado during waste retrieval and replacement operations. All of the contents of the breached drums are assumed to become airborne and one percent is assumed to be respirable. The tornado dispersion model of Pepper 1978 was used in the calculation. Since data is not available on the probability of occurrence for each tornado classification, it was assumed that the tornado frequency reported by Boyle, et al. 1978 was applicable for the F-1 tornado in Pepper 1978. The resulting risks are presented in Table 7-3.

7.4.3 Process Incidents

The process incidents assessed for this alternative include a nuclear excursion, a fire and a waste handling accident. Considerations for a nuclear excursion are the same as those discussed in Subsection 7.3.3 for Alternative 1. Considerations for the other two incidents are discussed below.

Fire: After the waste containers have been surrounded by clay, very little air would be available to support combustion. The risk from a fire in a waste container would thus be negligibly small.

Waste Handling Accident: Because the waste containers have to be temporarily removed from the storage facilities to construct the clay liners, there is a possibility that one of the waste containers will be dropped and breached. The handling accident that results in the largest risk is a dropped waste container accompanied by fire. It is assumed that the container that drops contains 10 times the average inventory for the given container type. One half of the contents of the dropped container are assumed to burn and one percent of the burned material is assumed to be respirable. The frequency of this event is based on 10^{-5} drops per handling operation and a probability of 10^{-2} fires per drop (USDOE 1979 a). The risks results are presented in Table 7-3.

7.4.4 Airplane Crash

The consequences of an airplane crash into the waste storage area after the improved confinement measures were implemented would be negligible. Risks during the period that the alternative was being implemented would be essentially the same as those calculated for Alternative 1 in Subsection 7.3.4.

7.4.5 Intrusion

The addition of the protective measures included in this alternative would make intrusion more difficult but would not preclude it. The scenario considered for Alternative 1 of a reclaimer searching for valuables is still considered as the limiting case. The maximum individual and population doses would thus be approximately the same as those calculated for Alternative 1 in Subsection 7.3.5.

7.5 ASSESSMENT OF RISKS FOR ALTERNATIVE 3A

This alternative consists of retrieving the waste, overpacking the existing waste containers and shipping the overpacks to a Federal repository (see Subsection 4.3.4.2). Overpacking of the drums and concrete casks would be performed in the field. Overpacking of the waste packages from the stainless steel lined wells would be performed in an existing facility at ORNL. The alternative is assumed to be implemented over a two-year period.

The events considered in assessing risks for this alternative are as follows:

- ROUTINE RELEASES
- NATURAL EVENTS
  - Earthquake
  - Flooding
  - Tornadoes
  - Meteorite
- PROCESS INCIDENTS
  - Fire
  - Nuclear Excursion
  - Waste Handling Accident
- AIRPLANE CRASH
- TRANSPORTATION
  - Routine
  - Accident

7.5.1 Routine Releases

Routine releases as a result of overpacking the existing waste containers are expected to be negligibly small. All of the waste, prior to overpacking, is in sealed containers. All of the containers except the buried casks can be easily inspected before being retrieved. Retrieval of the buried casks will be performed inside a negative pressure structure. If any leaking or suspect containers are detected, the overpacking operation for them will be performed inside the negative pressure structure.

7.5.2 Natural Events

Earthquakes, flooding, high winds and meteorite strikes are the natural events that are considered in the risk assessment for this alternative.

Earthquakes: No release of activity as a result of an earthquake is expected for reasons similar to those discussed in Subsection 7.3.2 for Alternative 1.

High Winds: The risks as a result of high winds are the same as those calculated for Alternative 2 in Subsection 7.4.2 with the exception that the period of susceptibility is the two-year period during which the overpacking operations would be performed.

Flooding: The elevations at either of the locations at which the overpack operations would be performed are substantially above the maximum probable flood levels expected at either location. Consequently, no activity release as the result of flooding is expected for this alternative.

Meteorite: The risk as a result of a meteorite strike during waste retrieval or overpack operation is expected to be no larger than that calculated for a large meteorite strike on the drum storage area in Subsection 7.3.2. The period of susceptibility is the two-year period assumed for retrieval and overpacking operations.

7.5.3 Process Incidents

Processing incidents for Alternative 3A are similar to those considered for the two previous alternatives.

Fire: Because the waste is all in sealed containers, there is very little access to air to support spontaneous combustion of the waste. Fire as a result of incidents occurring during waste retrieval or overpacking is considered below in the assessment of waste handling accidents.

Nuclear Excursion: Since the overpacking operation will not result in a redistribution of the fissile material, a nuclear excursion is not expected to occur, for reasons similar to those discussed in Subsection 7.3.3.

Waste Handling Accident: The waste handling accident that is expected to result in the largest risk is a dropped waste container accompanied by fire. The consequences of this accident are calculated with the same assumptions used for Alternative 2 in Subsection 7.4.3. In the risk calculation, a lower event frequency is used because of fewer handling operations and a longer implementation period (two years). The resulting risks are presented in Table 7-4.

7.5.4 Airplane Crash

The risk of an airplane crash during waste retrieval and overpacking operations is the same as that calculated for Alternative 1 in Subsection 7.3.4 with the exception that the time period during which the risk is incurred is the two-year period during which the operations take place. The risk values are presented in Table 7-4.

7.5.5 Transportation

Routine Shipments: Dose commitments as the result of routine shipment of the waste to the Federal repository is calculated using the models discussed in USAEC 1972 and Taylor and Daniel 1977. The maximum individual would be a rail crewman that rides on every shipment of waste to the repository. This is a conservative assumption since it is highly improbable that the same crew would be used on each shipment. The distance to the Federal repository is assumed to be 4,000 kilometers (see Section 1.0). The route was assumed to be five percent urban, five percent suburban, and 90 percent rural. The train speed is assumed to be 24, 40 and 64 kilometers per hour (15, 25 and 40 miles per hour) for the urban, suburban and rural portions of the route, respectively. Approximately 80 shipments per year would be required. The source strength of each shipment was assumed to be equal to the transportation limit for a sole use vehicle, i.e., 10 mr/hr at a distance of 1.8 meters (6 feet) from the railcar. A source crew distance of 152 meters (500 feet) was used based on USAEC 1972.

The maximum population dose was based on the same assumptions described above. The average population density along the rail route was assumed to be 3,861 people/km^2 for urban areas, 719 people/km^2 for suburban areas, and 7.1 people/km^2 for rural areas (USDOE 1979 a). The dose for a rail crew of five was also included in the population dose.

The maximum individual and population exposures calculated using the above assumptions are presented in Table 7-4.

Accidents: Because of the design of the ATMX 600 railcar, it is assumed that an accident in the extra severe category of USAEC 1972 would be required in order to cause a significant release of activity. The probability of a rail accident in this category is 8.1×10^{-12} per vehicle kilometer (1.3×10^{-11} per vehicle mile). It is assumed that an extra severe accident is not possible in the urban portion of the rail route because of the lower speeds used in such areas.

Release of activity from the accident is calculated assuming that the railcar involved contains twice the average isotopic inventory. All of the combustible material in the railcar is assumed to burn with one percent of the burned material being respirable.

U.S. Nuclear Regulatory Commission Regulatory Guide 1.4 (USNRC 1974) was used in determining atmospheric dispersion of the released activity. The maximum individual was assumed to be located at 100 meters. The affected population was assumed to be uniformly distributed along the rail route at a uniform density calculated using the proportion of suburban and rural routing given above.

The doses and risks calculated for a rail accident using the assumptions discussed above are given in Table 7-4.

7.6 ASSESSMENT OF RISKS FOR ALTERNATIVE 3B

For Alternative 3B, drums and waste packages are retrieved and overpacked as in Alternative 3A. The concrete casks are retrieved and transported to a repackaging facility where they are emptied. The waste is sized reduced, as required, and placed in 0.208 cubic meter (55 gallon) drums. The overpacked containers and the 0.208 cubic meter drums are shipped via rail to a Federal repository. The period over which the waste would be processed and shipped is estimated to be two years. Additional details of Alternative 3B are given in Subsection 4.3.4.3.

The events considered in the risk assessment for this alternative are the same as those considered for Alternative 3A with the addition of two additional process incidents: failure of a filter in the repackaging facility and an explosion in the facility.

7.6.1 Routine Releases

Routine releases as a result of repackaging are calculated assuming that 10^{-5} of the activity being processed becomes airborne and is respirable (USDOE 1979 a). The airborne activity would be processed through two sets of

HEPA filters with a decontamination factor of 10^6. The resulting dose commitments to the maximum individual and maximum population sector are presented in Table 7-5.

7.6.2 Natural Events

The risks as a result of natural events are the same as those calculated for Alternative 3A in Subsection 7.5.2. The risks associated with the effects of natural events at the repackaging facility are negligible in comparison.

7.6.3 Process Incidents

Process incidents which are considered for this alternative include explosions, nuclear excursions, filter failures, fires and waste handling accidents. The assumptions used and results of the assessment of these events is discussed below. The calculated risks and dose commitments are presented in Table 7-5.

Risks associated with an explosion or a nuclear excursion are considered to be negligible for this alternative. The only material in the waste which might explode during handling are slightly pressurized aerosol cans. Consequently, no significant release of activity is expected as the result of an explosion. The amount of fissile material allowed in the waste containers is under stringent administrative controls (see Subsection 7.3.3). The repackaging operation will result in very little increase in the effective density of the fissile material and so the likelihood of a nuclear excursion occurring is considered to be negligible.

Filter Failure: For this incident, it is assumed that one set of HEPA filters fails during the repackaging operations lowering the decontamination factor of the filtration system to 10^3. The cask being processed during this filter failure is assumed to contain 10 times the average cask activity and 10^{-5} (USDOE 1979 a) of this activity becomes airborne. An event frequency of 10^{-1} per year (USDOE 1979 a) was used in determining risk.

Fire: The limiting case considered for this event is a fire that occurs in the waste material after a cask has been opened in the repackaging facility. It is assumed that the affected material contains 10 times the average cask activity and that one half of it burns and becomes airborne. One percent of the material that burns is assumed respirable. As a result of the fire, one set of HEPA filters is assumed to become inoperable lowering the decontamination factor of the air filtration to 10^3. Risks are determined based on an event frequency of 10^{-2} per year (USDOE 1979 b).

Waste Handling Accident: During waste retrieval, repackaging, overpacking and shipping operations, a waste handling accident could occur. The activity release as the result of a handling accident could range from negligible to the loss of a significant fraction of the activity in the affected container. The accident of this type that results in the largest risk is a container that is dropped during waste retrieval operations and is accompanied by fire. The assumptions used in determining risk are the same as those used for Alternative 3A in Subsection 7.5.3.

7.6.4 Airplane Crash

The risks as a result of an airplane crash are essentially the same as those calculated for Alternative 3A in Subsection 7.5.4. The risks associated with the impact of an airplane on the repackaging facility are negligible in comparison.

7.6.5 Transportation

The calculation of doses and risks for both routine shipments and for accidents is based on the same assumptions used for Alternative 3A in Subsection 7.5.5 with the exception that 70 railcars per year are estimated to be required. Fewer railcars are required because the repackaging allows more waste per railcar to be shipped. The calculated doses and risks are presented in Table 7-5.

7.7 ASSESSMENT OF RISKS FOR ALTERNATIVE 3C

For this alternative, the waste packages from the stainless steel lined wells are overpacked as in Alternative 3A and 3B. The waste stored in drums and concrete casks is retrieved and transported to a compaction facility. The waste containers are emptied and minimal sorting is performed to remove items that are too large to fit in a 0.208 cubic meter (55 gallon) drum or that would interfere with the compaction process. The sorted items are sized reduced and added to the remaining waste which is compacted into 0.208 cubic meter drums and shipped to a Federal repository. The retrieval, processing and shipping operations for this alternative are estimated to require three years. A more detailed description of Alternative 3C is given in Subsection 4.3.4.4.

The events considered in the Alternative 3C risk assessment are the same as those considered for Alternative 3B.

7.7.1 Routine Releases

Routine releases are calculated in a manner similar to that described for Alternative 3B in Subsection 7.6.1. The waste inventory used in the calculation is larger since the contents of both drums and casks is being processed. The releases occur over the estimated three-year processing period. The calculated dose commitments and risks are presented in Table 7-6.

7.7.2 Natural Events

The period of susceptibility to risks from natural events is the estimated three-year processing period. For all natural events except tornados, the risks are the same as those calculated for Alternative 3A in Subsection 7.5.2. The risks associated with the effect of a tornado on the containers in interim storage at the compaction facility are significant in comparison to those determined in Subsection 7.5.2. This additional risk is calculated assuming a four-week backlog of containers in interim storage is breached as the result of a tornado. The remaining assumptions used are the same as those presented in Subsection 7.5.2. The resulting dose commitments and risks associated with natural events are presented in Table 7-6.

7.7.3 Process Incidents

Calculation of risks for Alternative 3C as a result of process incidents is similar to that done for 3A in Subsection 7.5.3 except that the analysis is based on a three-year processing period.

The increase in the density of the waste as a result of compaction could affect the probability of a nuclear excursion occurring. However, the administrative limits used at ORNL are sufficiently conservative that even with the maximum volume reduction factor possible, an infinite array of drums with compacted waste would be safely subcritical.

7.7.4 Airplane Crash

The risks as a result of an airplane crash are the same as those calculated for Alternatives 3B in Subsection 7.6.4 with the exception that the time integrated risks are larger because of the three-year processing period. The risks associated with an airplane crashing into the compaction facility are negligible in comparison.

7.7.5 Transportation

The calculation of doses and risks for routine shipments and for accidents is based on the same assumptions used for Alternative 3A in Subsection 7.5.5 with the exception that fewer shipments per year would be required. Based on the volume reduction achieved by use of compaction and size reduction, approximately 35 railcars per year are estimated to be required for shipment of the waste to the Federal repository.

7.8 ASSESSMENT OF RISKS FOR ALTERNATIVES 3D AND 3E

Assessment of risks for Alternatives 3D and 3E are considered together, since no differences were identified which would result in significantly different risks for the two alternatives. For either alternative, the waste packages from the stainless steel lined wells are overpacked as in Alternative 3A. The waste stored in drums and concrete casks is retrieved and transported to an incineration facility. The waste containers are emptied and minimal sorting is performed to remove items that are too large to fit in a 0.208 cubic meter drum.

For Alternative 3D, bulk metal items which would interfere with the incineration process would also be sorted. The sorted waste would be incinerated in a molten glass incinerator. The glass and ash mixture would be cast into 0.208 cubic meter drums. The sorted items would be sized reduced and packaged without additional processing in 0.208 cubic meter drums. Both sets of drums would be shipped by railcar to a Federal repository.

For Alternative 3E, the sorted waste would be incinerated in a rotary kiln. The sorted items would be sized, reduced and combined with the incineration residue from the rotary kiln in a slag immobilization unit. The slag would be cast in drums and shipped by railcar to a Federal repository. The incinerator for either alternative is assumed to be sized to process the waste over a five-year period.

Additional details about Alternatives 3D and 3E are given in Subsections 4.3.4.5 and 4.3.4.6.

The events considered in the risk assessment are the same as those considered for Alternative 3C.

7.8.1 Routine Releases

The assumptions used in calculating routine releases are the same as those described in Subsection 7.7.1 for Alternative 3C with the exception that the fraction of activity that becomes airborne is assumed to be an order of higher magnitude because of the increased complexity and higher temperatures associated with the processing method. The releases occur over the five-year processing period. The calculated dose commitments and risks are presented in Table 7-7.

7.8.2 Natural Events

The risks as a result of natural events is calculated in the same manner as those described in Subsection 7.7.2 for Alternative 3C. The susceptibility period is the five-year processing period. The number of waste containers at risk for a tornado at the incineration facility is somewhat less since the longer processing period results in fewer containers in interim storage.

7.8.3 Process Incidents

Calculations of risks from process incidents such as filter failure, fire and waste handling accidents are similar to Alternative 3C in Subsection 7.7.3 except the event frequency and time-integrated risks are affected by the five-year processing period. In addition, risks as the result of an incinerator malfunction leading to an explosion are calculated. As a result of the explosion, one of the HEPA filters is assumed to fail lowering the atmospheric cleanup decontamination factor to 10^3. The waste inventory in the incinerator at the time of the explosion is assumed to be 100 pounds which is completely released to the building atmosphere.

The fraction of activity assumed to be respirable is 10 percent (USDOE 1979 b). An event frequency of 10^{-3} per year was used in calculating risks (USDOE 1979 b). The results of the calculation are given in Table 7-7.

Neither risks nor consequences associated with a nuclear excursion are calculated because of the difficulty in defining a limiting scenario and determining event frequency.

7.8.4 Airplane Crash

The risks as a result of an airplane crash are the same as those calculated for Alternative 3B in Subsection 7.6.4 with the exception that the time-integrated risks are larger because of the five-year processing period.

7.8.5 Transportation

The calculation of doses and risks for routine shipments and for accidents is based on the same assumptions used for Alternative 3A in Subsection 7.5.5 except as noted below:

A. Approximately 20 railcars per year are estimated to be required for shipping waste to the Federal repository.

B. Because of the waste form for this alternative, the waste will not burn. Consequently, the only mechanism that would cause the waste to become airborne is the impact force during the accident shattering the waste form into particles of respirable size. The respirable fraction from this mechanism was assumed to be 10^{-4} (USDOE 1979 a).

The calculated risks and dose commitments are presented in Table 7-7.

TABLE 7-1 HEALTH EFFECTS PARAMETERS FOR INHALATION PATHWAY

Isotope	Organ	Inhalation Dose in rem	Cancer Fatalities per 10^6 rem		Fatalities per Whole Body Dose in rem
Pu-238	WB[a]	1.000	200		2.00E - 04[c]
	Bone	39.700 x WB[b]	16		6.35E - 04
	Lung	2.640 x WB	40		1.06E - 04
	Liver	5.610 x WB	15		8.42E - 05
	Kidney	4.290 x WB	15		6.44E - 05
				Total	1.09E - 03
Pu-239	WB	1.000	200		2.00E - 04
	Bone	41.200 x WB	16		6.59E - 04
	Lung	2.220 x WB	40		8.88E - 05
	Liver	5.560 x WB	15		8.34E - 05
	Kidney	4.260 x WB	15		6.39E - 05
				Total	1.10E - 03
Pu-240	WB	1.000	200		2.00E - 04
	Bone	41.100 x WB	16		6.58E - 04
	Lung	2.220 x WB	40		8.88E - 05
	Liver	5.550 x WB	15		8.34E - 05
	Kidney	4.260 x WB	15		6.39E - 05
				Total	1.09E - 03
Am-241	WB	1.000	200		2.00E - 04
	Bone	15.100 x WB	16		2.42E - 04
	Lung	0.903 x WB	40		3.61E - 05
	Liver	5.350 x WB	15		8.03E - 05
	Kidney	7.510 x WB	15		1.13E - 04
				Total	6.71E - 04
Cm-244	WB	1.000	200		2.00E - 04
	Bone	16.800 x WB	16		2.69E - 04
	Lung	1.730 x WB	40		6.92E - 05
	Liver	7.240 x WB	15		1.09E - 04
	Kidney	4.670 x WB	15		7.00E - 05
				Total	7.17E - 04
Cf-252	WB	1.000	200		2.00E - 04
	Bone	42.000 x WB	16		6.72E - 04
	Lung	8.540 x WB	40		3.42E - 04
	Liver	No data	15		-
	Kidney	No data	15		-
				Total	1.21E - 03

Notes:

a. Whole body

b. 39.700 x WB for the inhalation bone dose for Pu-238 means that bone dose from inhalation of Pu-238 is 39.7 times dose to whole body from inhalation of this isotope.

c. 2.00E - 04 same as 2.00×10^{-4}

TABLE 7-2 SUMMARY OF DOSE COMMITMENTS AND RISKS FOR ALTERNATIVE I

Event	Maximum Individual		Maximum Population			Estimated Cancer Fatalities
	Dose Commitment (rem/event)	Risk (rem/yr)	Dose Commitment (man-rem/event)	Risk (man-rem/yr)	Time-Integrated Risk (man-rem)	
Routine Releases	3.1	3.1	6.8E + 01[a]	6.8E + 01	1.6E + 04	1.2E + 01
Natural Events						
Earthquake	(b)	(b)	(b)	(b)	(b)	(b)
Flooding	(b)	(b)	(b)	(b)	(b)	(b)
High Winds	(b)	(b)	(b)	(b)	(b)	(b)
Meteorite	6.4E + 04	6.4E - 06	1.2E + 08	1.2E - 02	2.5E + 01	1.9E - 03
Erosion	(b)	(b)	(b)	(b)	(b)	(b)
Process Incidents						
Fire	2.0E + 01	2.0E - 01	3.4E + 04	3.4E + 02	3.5E + 05	2.8E + 02
Nuclear Excursion	(b)	(b)	(b)	(b)	(b)	(b)
Airplane Crash	3.8E + 04	1.6E - 04	6.2E + 07	2.7E - 01	5.4E + 01	4.1E - 02
Intrusion	1.6E + 03	(c)	3.2E + 03	(c)	(c)	(c)

Notes:

a. 6.8E + 01 same as 6.8×10^1

b. Negligible

c. Not calculated because of difficulty in reliably estimating event frequency.

TABLE 7-3 SUMMARY OF DOSE COMMITMENTS AND RISKS FOR ALTERNATIVE 2

Event	Maximum Individual		Maximum Population			Estimated
	Dose Commitment (rem/event)	Risk (rem/yr)	Dose Commitment (man-rem/event)	Risk (man-rem/yr)	Time Integrated Risk (man-rem)	Cancer Fatalities
Routine Releases	(a)	(a)	(a)	(a)	(a)	(a)
Natural Events						
Earthquake	(a)	(a)	(a)	(a)	(a)	(a)
Flooding	(a)	(a)	(a)	(a)	(a)	(a)
High Winds	1.9E - 03[b]	6.8E - 08	1.7E + 01	6.1E - 04	6.0E - 04	4.8E - 07
Meteorite	6.4E + 04	6.4E - 06	1.2E + 08	1.2E - 02	2.5	1.9E - 03
Erosion	(a)	(a)	(a)	(a)	(a)	(a)
Process Incidents						
Fire	(a)	(a)	(a)	(a)	(a)	(a)
Nuclear Excursion	(a)	(a)	(a)	(a)	(a)	(a)
Waste Handling Accident	4.4E + 02	1.1E - 01	5.5E + 05	1.7E + 02	1.6E + 02	1.3E - 01
Airplane Crash	3.8E + 04	1.6E - 04	6.2E + 07	2.7E - 01	1.3E - 01	1.1E - 04
Intrusion	1.6E + 03	(c)	3.2E + 03	(c)	(c)	(c)

Notes:

a. Negligible

b. 1.9E - 03 same as 1.9×10^{-3}

c. Not calculated because of difficulty in reliably estimating event frequency.

TABLE 7-4 SUMMARY OF DOSE COMMITMENTS AND RISKS FOR ALTERNATIVE 3A

Event	Maximum Individual Dose Commitment (rem/event)	Maximum Individual Risk (rem/yr)	Maximum Population Dose Commitment (man-rem/event)	Maximum Population Risk (man-rem/yr)	Maximum Population Time Integrated Risk (man-rem)	Estimated Cancer Fatalities
Routine Releases	(a)	(a)	(a)	(a)	(a)	(a)
Natural Events						
Earthquake	(a)	(a)	(a)	(a)		
Flooding	(a)	(a)	(a)	(a)		
High Winds	1.9E - 03[b]	6.8E - 08	1.7E + 01	6.1E - 04	1.2E - 03	9.3E - 07
Meteorite	6.4E + 04	6.4E - 06	1.2E + 08	1.2E - 02	1.2E - 02	9.6E - 06
Process Incidents						
Fire	(a)	(a)	(a)	(a)	(a)	(a)
Nuclear Excursion	(a)	(a)	(a)	(a)	(a)	(a)
Waste Handling Accident	4.4E + 02	2.6E - 02	5.5E + 05	3.9E + 01	7.5E + 01	5.8E - 02
Airplane Crash	3.8E + 04	1.6E - 04	6.2E + 07	2.7E - 01	2.6E - 01	2.1E - 04
Transportation						
Routine	1.5E - 02	1.5E - 02	2.7	2.7	5.4	1.1E - 03
Accident	4.9E + 04	4.9E - 02	4.1E + 05	4.1E - 01	7.7E - 01	6.2E - 04

Notes:

a. Negligible

b. 1.9E - 03 same as 1.9×10^{-3}

TABLE 7-5 SUMMARY OF DOSE COMMITMENTS AND RISKS FOR ALTERNATIVE 3B

Event	Maximum Individual Dose Commitment (rem/event)	Maximum Individual Risk (rem/yr)	Maximum Population Dose Commitment (man-rem/event)	Maximum Population Risk (man-rem/yr)	Maximum Population Time Integrated Risk (man-rem)	Estimated Cancer Fatalities
Routine Releases	1.9E - 08[a]	1.9E - 08	8.1E - 05	8.1E - 05	1.5E - 04	1.2E - 07
Natural Events						
Earthquake	(b)	(b)	(b)	(b)	(b)	(b)
Flooding	(b)	(b)	(b)	(b)	(b)	(b)
High Winds	1.9E - 03	6.8E - 08	1.7E + 01	6.1E - 04	1.2E - 03	9.3E - 07
Meteorite	6.4E + 04	6.4E - 06	1.2E + 08	1.2E - 02	1.2E - 02	9.6E - 06
Process Incidents						
Fire	3.3E - 01	3.3E - 03	5.5E + 02	5.5	1.0E + 01	7.8 - 03
Nuclear Excursion	(b)	(b)	(b)	(b)	(b)	(b)
Waste Handling Accident	4.4E + 02	2.6E - 02	5.5E + 05	3.9E + 01	7.5E + 01	5.8E - 02
Filter Failure	6.7E - 04	6.7E - 05	1.1	1.1E - 01	2.1E - 01	1.6E - 04
Explosion	(b)	(b)	(b)	(b)	(b)	(b)
Airplane Crash	3.8E + 04	1.6E - 04	6.2E + 07	2.7E - 01	2.6E - 01	2.1E - 04
Transportation						
Routine	1.3E - 02	1.3E - 02	2.3	2.3	4.7	9.4E - 04
Accident	4.9E + 04	5.0E - 02	4.1E + 05	4.2E - 01	8.0E - 01	6.3E - 04

Notes:

a. 1.9E - 08 same as 1.9×10^{-8}

b. Negligible

TABLE 7-6 SUMMARY OF DOSE COMMITMENTS AND RISKS FOR ALTERNATIVE 3C

Event	Maximum Individual Dose Commitment (rem/event)	Maximum Individual Risk (rem/yr)	Maximum Population Dose Commitment (man-rem/event)	Maximum Population Risk (man-rem/yr)	Maximum Population Time-Integrated Risk (man-rem)	Estimated Cancer Fatalities
Routine Releases	4.0E - 08[a]	4.0E - 08	1.8E - 04	1.8E - 04	4.9E - 04	3.8E - 07
Natural Events						
Earthquake	(b)	(b)	(b)	(b)	(b)	(b)
Flooding	(b)	(b)	(b)	(b)	(b)	(b)
High Winds	5.4E - 03	2.0E - 07	4.9E + 01	1.8E - 03	4.9E - 03	3.9E - 06
Meteorite	6.4E + 04	6.4E - 06	1.2E + 08	1.2E - 02	1.8E - 02	1.4E - 05
Process Incidents						
Fire	3.3E - 01	3.3E - 03	5.5E + 02	5.5	1.5E + 01	1.1E- 02
Nuclear Excursion	(b)	(b)	(b)	(b)	(b)	(b)
Waste Handling Accident	4.4E + 02	1.8E - 02	5.5E + 05	2.6E + 01	7.3E + 01	5.7E - 02
Filter Failure	6.7E - 04	6.7E - 05	1.1	1.1E - 01	3.1E - 01	2.3E - 04
Explosion	(b)	(b)	(b)	(b)	(b)	(b)
Airplane Crash	3.8E + 04	1.6E - 04	6.2E + 07	2.7E - 01	3.8E - 01	3.1E - 04
Transportation						
Routine	6.6E - 03	6.6E - 03	1.2	1.2	3.5	7.0E - 04
Accident	3.4E + 04	3.0E - 02	2.8E + 05	2.6E - 01	7.1E - 01	5.6E - 04

Notes:

a. 4.0E - 08 same as 4.0×10^{-8}

b. Negligible

TABLE 7-7 SUMMARY OF DOSE COMMITMENTS AND RISKS FOR ALTERNATIVES 3D AND 3E

Event	Maximum Individual		Maximum Population			Estimated Cancer Fatalities
	Dose Commitment (rem/event)	Risk (rem/yr)	Dose Commitment (man-rem/event)	Risk (man-rem/yr)	Time-Integrated Risk (man-rem)	
Routine Releases	2.4E - 07[a]	2.4E - 07	1.1E - 03	1.1E - 03	4.7E - 03	3.6E - 06
Natural Events						
Earthquake	(b)	(b)	(b)	(b)	(b)	(b)
Flooding	(b)	(b)	(b)	(b)	(b)	(b)
High Winds	3.1E - 03	1.1E - 07	2.8E + 01	1.0E - 03	4.6E - 03	3.6E - 06
Meteorite	6.4E + 04	6.4E - 06	1.2E + 08	1.2E - 02	2.85E - 02	2.3E - 05
Process Incidents						
Fire	3.3E - 01	3.3E - 03	5.5E + 02	5.5	2.5E + 01	1.8E - 02
Nuclear Excursion	(c)	(c)	(c)	(c)	(c)	(c)
Waste Handling Accident	4.4E + 02	1.1E - 02	5.5E + 05	1.6E + 01	7.0E + 01	5.4E - 02
Filter Failure	6.7E - 04	6.7E - 05	1.1	1.1E - 01	4.9E - 01	3.6E - 04
Explosion	7.8E - 02	7.8E - 05	1.3E + 02	1.3E - 01	5.5E - 01	4.5E - 04
Airplane Crash	3.8E + 04	1.6E - 04	6.2E - 07	2.7E - 01	6.2E - 01	4.9E - 04
Transportation						
Routine	3.8E - 03	3.8E - 03	6.7E - 01	6.7E - 01	3.3	6.7E - 04
Accident	6.7E + 02	3.6E - 04	5.7E + 03	3.1E - 03	1.4E - 02	1.1E - 05

Notes:

a. 2.4E - 07 same as 2.4×10^{-7}

b. Negligible

c. Not calculated because of difficulty in defining limiting scenario and event frequency.

SECTION 8.0

COST ASSESSMENT

SECTION 8.0
COST ASSESSMENT

8.1 GENERAL

Cost estimates have been prepared for each of the alternatives identified in Section 4.0. The intent in preparing these estimates was to determine the order of magnitude costs suitable for comparing the alternatives. The estimates are based on limited design information and as such have large uncertainties. The additional design and cost studies that would be required to produce estimates suitable for budgetary purposes is beyond the scope of the present effort.

The implementation for all alternatives is assumed to be 1995. The cost estimate for a given alternative includes the capital cost of facilities and improvements associated with the alternative, plus the operations and maintenance (O&M) costs, transportation costs, decontamination and decommissioning (D&D) costs and contingency. The O&M costs for those alternatives involving continued surveillance are included for a 100-year period after 1995. Costs for all other alternatives include those incurred up to receipt of the waste at a Federal repository but do not include charges for disposal of the waste at the repository. Costs for additional development work that would be required prior to implementation of an alternative such as that discussed in Subsections 5.1.3.2 and 5.1.3.3 for Alternatives 3D and 3E is also not included.

Because of the long time period involved prior to implementing the alternatives, the cost estimates are reported in mid-1980 dollars. The determination of present worth or escalation of costs to the projected construction periods would not provide meaningful results.

8.2 METHODOLOGY

8.2.1 Capital Costs

Capital costs of facilities or improvements include engineering, construction materials, construction labor costs and inspection. Cost data were based on

Smith 1978, FMC 1978 and industry standards. In addition, verbal quotes from suppliers and cost estimate data for the Rocky Flats incinerator projects, the proposed Allis Chalmers' Kilngas Facility and the Waste Isolation Pilot Plant were used in preparing the capital cost estimates.

8.2.2 Operations and Maintenance Costs

The O&M costs include the salaries of O&M personnel, the costs for energy consumption and supplies needed to perform the operations required for each alternative and the cost of replacement equipment. The costs associated with O&M personnel, supplies and replacement of equipment were based on engineering judgement. Energy consumptions costs were based on data for similar facilities.

8.2.3 Transportation Costs

The estimated weight and volume of the waste packages being shipped were used in determining transportation costs. Shipping rates were obtained from the Southern Railway Company for standard trains. The cost of transport shields required to meet shipping requirements was included as part of the transportation costs. Costs for the use of ATMX 600 railcars were not available for inclusion in the cost estimates, but they are not expected to significantly increase the estimated transportation costs.

8.2.4 Decontamination and Decommissioning Costs

Because of the difficulty in estimating the degree of decontamination required and the D&D criteria that would be in effect at the time any of the facilities are decommissioned, D&D costs were estimated assuming that they would be 10 percent of the capital cost of the facilities including contingency.

8.2.5 Contingency

Contingency is provided as a separate cost category. Contingency was determined by assessing the basis of each component part in the estimates and combining these individual factors to determine an overall value for contingency for each alternative.

8.3 COST ESTIMATES

Cost estimates for each category described above are presented in Table 8-1. A discussion of the costs for each alternative is given below.

8.3.1 Alternative 1

The estimated cost of this alternative is \$3.4 million. The costs are all O&M costs since no facilities, site improvements, transportation of waste, or D&D is required for this alternative. The O&M estimate includes the cost of surveillance, maintenance and security as defined in Subsection 4.1. It should be noted that these costs are incurred over a 100-year period, and that escalation during this period has not been included.

8.3.2 Alternative 2

Alternative 2 is estimated to cost \$11.2 million. Approximately 30 percent of this amount is the capital cost of the improved confinement measures, the portable structures for retrieving the buried casks and the additional structures required to hold the waste because of the space occupied by the clay linings. The remainder of the estimated total is contingency plus the O&M costs associated with surveillance, maintenance and security for a 100-year period and waste retrieval and replacement operations. Once again, it should be noted that the costs incurred over the 100-year period have not been escalated.

8.3.3 Alternative 3A

The estimated cost of Alternative 3A is \$10.9 million. Although this cost is approximately the same as that for Alternative 2, the distribution of costs is different. The capital costs for this alternative includes only the cost of the portable buildings required for retrieving the buried casks. Most of the estimated total is the O&M costs for retrieving and overpacking the waste and the transportation costs for shipment of the waste to a Federal repository. Disposal costs at the repository have not been included and would increase the total cost of this alternative with respect to Alternatives 1 and 2.

8.3.4 Alternatives 3B, 3C, 3D and 3E

The estimated costs of Alternatives 3B, 3C, 3D and 3E are \$39.1, \$38.7, \$55.0 and \$56.7 million. Almost all of the cost differential between Alternative 3A and these alternatives can be attributed to the facilities necessary for these alternatives. The largest fraction of the differential cost is attributable to the capital cost of the facilities; however, the additional O&M costs plus the D&D costs and the increase in contingency also contribute a sizable fraction. The differential in cost between Alternatives 3B/3C and 3D/3E is primarily due to the special equipment and increase in complexity for the latter two alternatives. Again disposal costs at the repository are not included and would increase the total cost of these alternatives.

TABLE 8-1 SUMMARY OF ESTIMATED COSTS[a]

Alternative	Description	Capital Cost	O&M Cost	Transportation Cost	D&D Cost	Contingency	Total
1	Leave waste as is. Continue monitoring, maintenance and security	$ NA[b]	$ 3.0	$ NA	$ NA	$ 0.4	$ 3.4
2	Improve confinement of waste. Continue monitoring, maintenance and security	3.2	5.7	NA	NA	2.3	11.2
3A	Overpack drums and casks as retrieved. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	0.2	5.8	3.2	NA	1.7	10.9
3B	Overpack drums as retrieved. Size reduce and repackage wastes from concrete casks in a repackaging facility. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	18.0	7.6	2.9	2.3	8.3	39.1
3C	Size reduce and compact waste from drums and casks in a compaction facility. Overpack waste packages from lined wells in Building 3525. Ship waste to Federal repository	18.4	7.2	2.4	2.4	8.3	38.7
3D	Incinerate waste from casks and drums in a molten glass incinerator. Size reduce and repackage bulk metal items. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	23.0	14.6	2.3	3.0	12.1	55.0

TABLE 8-1 SUMMARY OF ESTIMATED COSTS[a]

Alternative	Description	Capital Cost	O&M Cost	Transportation Cost	D&D Cost	Contingency	Total
3E	Incinerate waste from casks and drums in a rotary kiln. Size reduce bulk metal items. Immobilize size reduced metal and incinerator residue using a basaltic slag. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	$22.5	$16.5	$ 2.3	$ 2.9	$12.5	$56.7

Note:

a. All costs are in millions of mid-1980 dollars.

b. Not applicable.

SECTION 9.0
COMPARISON OF ALTERNATIVES

SECTION 9.0
COMPARISON OF ALTERNATIVES

9.1 GENERAL

This section provides an overall evaluation and comparison of the alternatives based on the evaluation factors presented in Sections 5.0 through 8.0. The factors considered in the comparison are risks, costs, environmental impact, regulatory factors and development needs. Quantitative values have been presented and discussed previously for costs and risks. The remaining factors are considered less amenable to quantitative comparison and thus are based on qualitative judgements. It is important to remember that a number of considerations such as repository waste acceptance criteria, licensing requirements, etc. that will have a significant impact on the decision of how to manage ORNL's retrievable TRU wastes are not well defined at this time. Consequently, the results of the comparison are predicated upon the continued validity of the assumptions used.

9.2 OVERALL EVALUATION OF ALTERNATIVES

Table 9-1 presents a summary tabulation of the evaluation factors considered. Non-radiological environmental impact is expected to be minimal for all of the alternatives. The advantages/disadvantages of the other factors vary among alternatives and are discussed in more detail below along with any resulting recommendations.

9.2.1 Alternative 1

The primary advantages of this alternative are that it requires the lowest expenditure (at least for the short term) and that no development work would be required for its implementation. The disadvantages include: a) of all options considered, the long term risks are by far the highest; b) it is the alternative least likely to receive continued regulatory approval if it is implemented for long term management instead of interim storage; c) long term costs for this alternative could be substantially higher than estimated if the waste containers deteriorate significantly; and d) inadvertent or deliberate contact with the waste would continue to be possible. Accordingly, this alternative should not be considered as an option for the long term management of ORNL's retrievable TRU waste.

9.2.2 Alternative 2

Alternative 2 is somewhat more costly than Alternative 1. However, risks are substantially less as a result of the improved confinement measures which: a) preclude the possibility of fire affecting the waste; b) reduce the possibility of waste migration; and c) decrease the possibility of inadvertent or deliberate contact with the waste but do not preclude it.

The primary disadvantage of this alternative is that insufficient information exists at present on the geohydrological characteristics of the waste storage area and the long term integrity of the improved confinement measures, to meaningfully assess the desirability of this alternative as a long term waste management option. The lack of this data also prevents a definite determination on the regulatory acceptance of this alternative. If the long term performance of the alternative can be shown to be favorable, then regulatory approval would depend on acceptance of the possibility of intrusion at some future date. Prior to a decision to implement Alternative 2, a more detailed investigation should be initiated to obtain the data necessary to determine the viability of this alternative as a long term waste management option. It is important that this determination be made while the waste containers are still intact so that direct retrieval methods can be utilized. The cost of the controlled retrieval methods, assumed for the buried casks, comprise over 25 percent of the estimated cost of this alternative. If controlled retrieval methods were required for all of the waste, the cost of implementing this alternative would increase significantly.

9.2.3 Alternative 3A

The advantages of this alternative include the following: a) cost and risks are comparable to those for Alternative 2; b) little, if any development work would be required to implement it; and c) the only significant existing regulatory difficulty directly affecting the alternative is the necessity of obtaining an exemption from DOT Type B packaging requirements by taking credit for the design of the transporting vehicles. The primary drawback for this alternative is that when a Federal repository becomes available, the waste acceptance criteria at the repository could preclude its consideration. However, even in this eventuality, overpacking the waste could still be a viable option for a strategy involving shipment of the waste to a central waste processing facility.

9.2.4 Alternatives 3B and 3C

The evaluation factors for these alternatives are very similar to those for Alternative 3A except that they are significantly more costly. These alternatives offer little advantage with respect to Alternative 3A and since they could have the same difficulty with repository waste acceptance criteria.

9.2.5 Alternatives 3D and 3E

Alternatives 3D and 3E are the most costly and require the most development work of all the alternatives considered. Risks for these alternatives are comparable to those of all the others with the exception of Alternative 1. The primary regulatory difficulty associated with these alternatives would be the same as that discussed previously for Alternative 3A: obtaining an exemption from DOT's type B packaging requirements. The primary advantage of Alternatives 3D and 3E with respect to the other Strategy 3 alternatives is that they would be expected to encounter the least difficulties in meeting waste acceptance criteria at the repository in the event that the criteria are different than those discussed in Section 10.0, Appendix B. It should be noted that the cost of this advantage is quite significant.

TABLE 9-1 COMPILATION OF EVALUATION FACTORS

Alternative	Description	Total Estimated Cost (Millions of 1980$)	Radiological Risk (Estimated Cancer Fatalities)	Regulatory Difficulties	Non-Radiological Environmental Impact	Development Needs
1	Leave waste as is. Continue monitoring, maintenance and security	$ 3.4	2.9E + 02[a] + intrusion	high	minimal	minimal
2	Improve confinement of waste. Continue monitoring, maintenance and security	11.2	1.3E - 01 + intrusion	(b)	minimal	medium
3A	Overpack drums and casks as retrieved. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	10.9	6.0E - 02	low[c]	minimal	low
3B	Overpack drums as retrieved. Size reduce and repackage wastes from concrete casks in a repackaging facility. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	39.1	6.8E - 02	low[c]	minimal	low
3C	Size reduce and compact waste from drums and casks in a compaction facility. Overpack waste packages from lined wells in Building 3525. Ship waste to Federal repository	38.7	7.0E - 02	low[c]	minimal	low

TABLE 9-1 COMPILATION OF EVALUATION FACTORS

Alternative	Description	Total Estimated Cost (Millions of 1980$)	Radiological Risk (Estimated Cancer Fatalities)	Regulatory Difficulties	Non-Radiological Environmental Impact	Development Needs
3D	Incinerate waste from casks and drums in a molten glass incinerator. Size reduce and repackage bulk metal items. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	$55.0	7.4E - 02	low[c]	minimal	high
3E	Incinerate waste from casks and drums in a rotary kiln. Size reduce bulk metal items. Immobilize size reduced metal and incinerator residue using a basaltic slag. Overpack waste from lined wells in Building 3525. Ship waste to Federal repository	56.7	7.4E - 02	low[c]	minimal	high

Notes:

a. 2.9E + 02 same as 2.9×10^2

b. Dependent on detailed evaluation of geohydrological characteristics of waste storage area and investigation of long term integrity of improved confinement measures.

c. Assumes that waste acceptance criteria are not sufficiently different from those described in Appendix B (in this report) to preclude alternative.

SECTION 10.0

APPENDICES

SECTION 10.0

APPENDICES

This section is comprised of the following Appendices:

Appendix A Description of ORNL Site Characteristics

Appendix B Repository Waste Acceptance Criteria

Appendix C Determination of Incineration Process for Alternatives Evaluation

Appendix D Effect of Planned Decontamination/Decommissioning Projects on Study Results

Appendix E References

APPENDIX A

APPENDIX A

DESCRIPTION OF ORNL SITE CHARACTERISTICS

The environmental characteristics of the ORNL site that are pertinent to the long term management of TRU radioactive wastes are described in this section. The principal natural environmental features described below that are relevant to the management of TRU wastes include geology/seismology, hydrology and meteorology. The salient features of other natural and human environmental characteristics are also briefly reviewed in order to assess the potential impacts resulting from the alternative management options.

A.1 LOCATION

The Oak Ridge National Laboratory is located in eastern Tennessee about 40 kilometers (25 miles) west of Knoxville and 240 kilometers (150 miles) east of Nashville. The reservation of about 260 square kilometers (160 square miles) is bounded on the northeast, southeast and southwest by the Clinch River and on the northwest by Black Oak Ridge. The area surrounding the reservation is generally rural in character. The location of the proposed processing facility is shown in Figure A-1.

A.2 TOPOGRAPHY ASSOCIATED WITH ALTERNATIVE WASTE MANAGEMENT OPTIONS

The area comprising the Oak Ridge reservation is dominated by a series of ridges and valleys formed during Early Cambrian to Early Mississippian times by the action of erosion on severely faulted and folded rocks. The area is situated within the Tennessee or southern section of the Valley and Ridge province (Figure A-2), of the Appalachian Highlands Division. This physiographic province, sometimes called the "Newer Appalachians," is characterized by the following geomorphic features: (1) marked parallelism of ridges and valleys, commonly trending in a northeast-southwest direction; (2) conspicuous influence of alternating strong and weak stratigraphic units upon topographic forms; (3) a few major transverse streams with significant development of subsequent drainage producing a trellis drainage pattern in most areas; (4) general accordance of summit levels; and (5) abundant water and wind gaps through resistant rock ridges indicating past cases of stream diversion.

Present ridge and valley topography is thus the result of differential erosion of alternating weak and resistant strata folded into a series of anticlines and synclines. Valleys are of variable width and bounded by steep slopes ascending to the adjacent, parallel ridges which are locally 60 to 150 meters (200 to 500 feet) high. Thus a hilly, rolling topography of moderate relief is indicative of the area.

In the immediate vicinity of the Oak Ridge Reservation, the succession of alternating ridges and valleys from southeast to northwest is as follows: Copper Ridge, Melton Valley, Haw Ridge, Bethel Valley, Chestnut Ridge, Bear Creek Valley, Pine Ridge, Gamble Valley, East Fork Ridge, East Fork Valley and Black Oak Ridge. The ridges of the more resistant sandstone, cherty dolomite and shale run parallel in a northeast-to-southwest direction. Each of the ridges attains elevations in excess of 360 meters (1,200 feet), whereas the valley bottoms range in elevation from 226 meters (741 feet) at the Clinch River to over 270 meters (900 feet). The maximum elevation in the X-10 area is 413 meters (1,356 feet) at Melton Hill, located on Copper Ridge. Thus the maximum local relief is 187 meters (615 feet). Most of ORNL is within Bethel Valley with some facilities being sited in Melton Valley.

Bethel Valley is a portion of an elongated, northeast-southwest trending trough developed upon a belt of non-resistant limestones and shaly limestones of the Chickamauga Formation. The Bethel Valley portion of this trough is 12 kilometers (7.5 miles) long and the floor has an average width of 300 meters (1,000 feet). The lowest point of the valley floor near ORNL is where White Oak Creek passes through Haw Gap at 235 meters (770 feet) elevation.

The portion of Bethel Valley near the X-10 site is drained by White Oak Creek and its tributaries (Figure A-3). White Oak Creek heads on Chestnut Ridge a short distance northeast of ORNL and flows through the southern portion of the Laboratory proper. Immediately south of the Laboratory the creek passes through a watergap in Haw Ridge and thence flows south-southeastward in Melton Valley where it is joined by Melton Branch. The drainage is impounded by an earth dam where Tennessee Highway 95 crosses the channel approximately 800 meters (one-half mile) above the stream mouth. The dam and release gate Oelevation 229 meters (750 feet) at topo form a small, shallow reservoir called White Oak Lake.

Characteristic of the Ridge and Valley Province, most drainage of the area is of the trellis type. The master stream of the area is the Clinch River, an incised, meandering stream. The Clinch, along with the Powell, Holston and Nolichucky-French Broad rivers form the headwaters of the Tennessee River.

A.3 GEOLOGY

A.3.1 Stratigraphy

The Oak Ridge site is located in the Valley and Ridge province of the Appalachian Highlands Physiographic Division of the eastern United States. Proximity of the site to the various physiographic provinces within the Appalachian Highlands is shown in Figure A-2. As the name Applachian Highlands implies, the area is characterized by rugged terrain that varies from rolling hills to mountains. Within 320 kilometers (200 miles) of the site, the physiographic provinces include Interior Low Plateaus, Appalchian Plateaus, Valley and Ridge, Blue Ridge and Piedmont.

Different layers of Paleozoic sedimentary rock, primarily limestone, dolomite and shale, comprise the ridges and valleys of the area. The four major bedrock units are the Rome, Conasauga, Knox and Chickamauga formations.

The Rome formation is a generally well cemented sandstone with a minor shale. It has a relatively low ability to transmit groundwater because of the presence of unenlarged fractures. The Conasauga group consists of thin limestone units interbedded with silty and slightly calcareous shale; fractures are evenly distributed. Permeability is associated with weathering changes of the rock above and below the water table. A more uniform flow of groundwater occurs here than in the other formations.

The Knox group primarily consists of thick beds of dolomite and limestone; permeability and porosity of the formation are unevenly distributed. As a result, there have been water localizations from fracturing and solution by groundwater movement in this formation.

The Chickamauga limestone is composed of thin beds of shaly limestone and shale. Porosity is low, and fractures have been enlarged by solution, although not as extensively as in the cavernous Knox group. Such fractures and solution channels permit the free movement of groundwater through a network of channels.

Table A-1 lists the principal bedrock formations in the Oak Ridge area.

A.3.2 Seismology

Two major-thrust faults, the Copper Creek and the White Oak Mountain, are recognized in the area. Both are traceable for a distance greater than 160 kilometers (100 miles) within the Valley and Ridge province as shown in Figure A-4, which is a fault map of the vicinity. In both faults, the Middle Cambrian Rome formation is thrust over the Middle Ordovician Chickamauga limestone. The Copper Creek fault occurs along the northwestern side of Haw Ridge and extends northeast across Tennessee. Further to the north is Whiteoak Mountain fault, which lies on the northwestern side of Pine Ridge and can be traced southwest across Tennessee. The Pilot Knob syncline is a northeast extension of the Whiteoak Mountain fault in East Fork Ridge. Numerous secondary tectonic displacements have also occurred in the area (USAEC 1962).

Since the youngest stratigraphic units mapped in the Valley and Ridge province of southern Appalachia are of Pennsylvanian age, geologists believe that all the structural features of the primary Appalachian system were formed by the end of the Paleozoic era during what is now called the Appalachian Revolution. Although numerous faults exist within the area, they all originated long ago during the orogenic period; apparently, major tectonic activity ceased completely thereafter. No physiographic evidence indicating tectonic activity, such as stream offsets, displacement of alluvial deposits, or dislocations of Plio-Pleistocene terrace materials, has been observed along any of these thrust-fault areas. Consequently, there is no reason to expect current or future translocations of these tectonic relics (Clark and Stearn 1968, McMaster 1963).

Recent seismic events that were capable of producing a shock in the Oak Ridge area and that were recorded in the literature since 1800 are listed in Table A-2. Data for the older earthquake incidents are largely estimates extrapolated from nonspecific newspaper reports. In addition, these 19th-century records generally show a definite bias toward earthquakes of considerable intensity, an attitude that reflects the inherent limitations of intensity measurements during that period. The inability to record low-intensity earthquakes also explains the fewer tectonic incidences recorded in the earlier time interval.

The more recent seismic records indicate that the Appalachian region extending from Chattanooga to southwestern Virginia averages one to two earthquakes per year. This seismic activity is not uniform, but consists of extended periods with no shocks, followed by a burst of earthquakes. The maximum shock experience in the Oak Ridge area was of intensity VI on the Modified Mercalli scale (MM) recorded on March 28, 1913. Great distant earthquakes, such as the New Madrid series of 1811 and 1812 and the Great Charleston Earthquake of 1886, have affected the site with intensities greater than or equal to the maximum intensity of shocks involving regions that surround the site (McMaster 1963). From a plot made on a map of the southeastern United States (Figure A-5) of the epicenters of earthquakes, the areas of continuing seismic activity can be identified (Algermissen 1969). The following four areas of major current tectonic mobility are:

1. The Mississippi Valley encompasses the New Madrid region of Arkansas, Kentucky, Missouri and Tennessee. This seismic province includes the epicenter of the great series of New Madrid earthquakes. This area lies more than 400 kilometers (250 miles) northwest of the site. The New Madrid quakes attained an intensity of V to VI in the Oak Ridge area.

2. The Lower Wabash Valley is located in the southern regions of Illinois and Indiana. A southern Illinois earthquake of MM intensity VII in 1968 was felt over a 400,000 square mile area including a mild shock of intensity II to III in the Oak Ridge vicinity. The site lies more than 370 kilometers (230 miles) southeast of this region of active seismicity.

3. Charleston, South Carolina was the site of one of the greatest historic earthquakes experienced in the eastern United States. The August 31, 1886, shock of MM intensity IX was felt over the entire eastern coast and registered an intensity of V to VI in the Oak Ridge region. Recurrent seismic activity continues in this area, which is 520 kilometers (325 miles) southeast of the site.

4. The Appalachian Mountains of eastern Tennessee and western North Carolina are centers that exhibit moderate seismic activity at the frequency of one to two shocks per year. Part of this seismic area lies only 80 kilometers (50 miles) east of the site and account for most of the seismicity native to the eastern Tennessee region.

As discussed previously, no correlation has been observed between recorded earthquakes on the Oak Ridge reservation and superficial tectonic structures of the Valley and Ridge province. During historic times, the zone of relatively high seismicity in the adjacent Blue Ridge province has involved only movements of low intensity that probably represent minor adjustments of highly disturbed rock formations (Algermissen 1969).

Algermissen (Algermissen 1969) prepared a seismic-risk map of the United States (Figure A-6) to assist in the establishment of design requirements for buildings in various segments of the country. Seismicity ratings were based either on a historical earthquake of considerable intensity or on frequency of seismic incidences regardless of intensity. The Oak Ridge reservation lies in what Algermissen designated as Seismic Zone 2, which is an area of moderate activity.

Algermissen and Perkins (Algermissen and Perkins 1976) provide probabilistic estimates for the frequency of occurrence of earthquakes of a given horizontal acceleration. It must be emphasized that their estimates apply only to foundations that are coupled to bedrock. Foundations on unconsolidated alluvium may experience up to three times as much horizontal acceleration. For foundations coupled to bedrock at any location within the southern Appalachian region (as, for example, ORNL), there is a 90 percent probability that the horizontal acceleration will not exceed seven percent of gravity (equivalent to a Modified Mercalli intensity of VII) in a 50-year period.

Algermissen and Perkins' probabilistic estimate agrees reasonably well with the seismic history on the ORNL site. Table A-2 lists five earthquakes in the last 165 years that produced a Modified Mercalli intensity of V to VI within the vicinity of Oak Ridge. During the same time interval, no earthquakes of Modified Mercalli intensity VII or higher were reported. Intensity VII earthquakes occur approximately one order of magnitude less frequently than intensity V to VI earthquakes. This suggests a recurrence interval on the order of 300 years for intensity VII earthquakes, an estimate that is consistent with Algermissen and Perkins' probabilistic estimate.

Damage caused by intensity VII earthquakes is not severe. Examples of damage to be expected are (Richter 1958): (1) weak chimneys broken off at the roof line, (2) damage to weak masonry of low standards of workmanship, (3) some cracks in masonry of ordinary workmanship, (4) fall of plaster, loose bricks and stones and (5) damage to concrete irrigation ditches. Earthquake damage as described above is expected to recur once in approximately 300 years, or it has a 10 percent probability of being exceeded once within a 50-year period at ORNL.

Although the Oak Ridge area experiences a moderate level of seismic activity, no incidence of surface deformation has been documented. Earthquakes of the types that occur within the region are common throughout the world. The shocks are of normal focus - 40 to 50 kilometers (25 to 30 miles) deep. However, hypocenters of such shocks do penetrate through bedrock to crystalline basement, since sedimentary strata extend to a depth of only five kilometers (three miles) (Project Management Corporation 1972). It is highly improbable that a shock of major intensity will occur in the Oak Ridge area for several thousand years to come (USAEC 1962). Forces from more seismically active areas will probably be dissipated by distance.

A.3.3 <u>Soil Description</u>

Since groundwater flow on the Oak Ridge reservation is described primarily by water-table conditions rather than by artesian conditions, the soils of the area play a major role in regulating water flow to the various spheres of the hydrological environment.

Swann and Associates (Swann, et al. 1942) completed a soil survey of Roane County, Tennessee for the U.S. Department of Agriculture in 1942, but the survey has not been updated to conform with current nomenclature. Moneymaker (Sims 1974) of the U.S. Soil Conservation Service is attempting to record the soils of Anderson County, Tennessee. Carroll (Carroll 1961) made a very general analysis of the soils of the Oak Ridge vicinity for the U.S. Geological Survey. The soils of the Walker Branch Watershed have been analyzed extensively in conjunction with a project to measure nutrient cycling within this experimental ecosystem (Curlin and Nelson 1968, Peters, et al. 1970). McMasters and Waller (McMaster and Waller 1965) have described the soils of the White Oak Creek Basin. Although the information from these studies is insufficient to permit the construction of a detailed soil map, the existing data have been combined and correlated to produce the general soil-association map given in Figure A-7.

The broad soil associations suggested in Figure A-7 can be subdivided further into three major soil classes. All the major soils in a given association fall within the category of upland residual soils. Residual soils are defined as those soils formed by the in-situ weathering of the rocks and minerals of the underlying geology (Millar, et al. 1958). Thus, corresponding with each of the four major stratigraphic units that occur extensively in this part of the Valley and Ridge province, is an association of residual soils.

Minor soils include residual soils that have arisen from minor geological strata and also two other soil classes - colluvial and local alluvial. Colluvium is a heterogeneous deposit of rock fragments and soil material accumulated primarily through gravitational forces at the bases of comparatively steep slopes. An azonal group of soils - developed from recently deposited materials, transported mainly by water and characterized by a weak modification of the original material by soil-forming processes - is known as alluvium. This group settles primarily along narrow drainageways and stream depressions. Table A-3 indicates the percentage distribution, by geological unit and by soil class, of each soil series of the White Oak Creek Basin. Similar proportions may be assumed for the remainder of the Oak Ridge reservation. Soils analagous to those described in Table A-3 occur extensively throughout the southeastern United States in the Coastal Plains, the Piedmont, the Appalachian Plateau and the Valley and Ridge province (Millar, et al. 1958). Such soils have developed under forests and contain an A horizon that is typically light colored and covers a tougher, clayey subsoil of red, yellow or mottled color (Carroll, 1961). The major soils are generally silty (grain size 0.06 to 0.002 millimeter) rather than sandy or clayey. However, considerable clay may be present in the B horizon (Carroll 1961, McMaster and Waller 1965). The Knox soils contain kaolinite as their principal clay, whereas illite and vermiculite constitute the bulk of Conasauga clay.

A.4 METEOROLOGY

A.4.1 Regional Climate

Oak Ridge National Laboratory is located in a broad valley between the Cumberland Mountains northwest of the area and the Great Smoky Mountains to the southeast. These mountain ranges are oriented northeast-southwest, and the valley between is corrugated by broken ridges 90 to 150 meters (300 to 500 feet) high parallel to the main valley. Storm tracks appear to travel from northwest to southeast; associated wind velocities are somewhat decreased by the mountains and ridges. Tornadoes rarely occur in the valley between the Cumberlands and the Smokies (Project Management Corporation 1977). In winter, the Cumberland Mountains have a moderating influence on the local climate by retarding the flow of cold air from the north and west.

Relatively warm summers and cool winters characterize continental climatic regions in the southeastern United States. Cold, dry air masses from Canada predominate in the winter. They usually undergo modification and warming as the air crosses the ridges or the Cumberlands and moves down the western slopes. Anticyclonic circulation of the atmosphere about the Bermuda-Azores high-pressure system results in a predominance of warm, moist air from the Gulf during the rest of the year (Landsberg 1974). For about 33 days each year, temperatures reach 32.2 degrees C (90 degrees F) or higher, and temperatures of -17.8 degrees C (zero degrees F) or lower are expected on one day each year. Temperatures of zero degrees C (32 degrees F) or lower normally occur N 82 days annually. Precipitation amounts are greatest during winter and early spring and are lowest in early autumn. A secondary precipitation maximum, associated with thundershower activity, occurs in July. The annual relative humidity averages 70 percent.

A.4.2 Local Climate

The climate of Oak Ridge is typical of the humid southern Appalachian region. The local climate is noticeably influenced by topography (Air Resources 1972). Prevailing winds are usually either up-valley from southwest to northeast (daytime) or down-valley from northeast to southwest (nighttime). Differences in elevation have a measurable influence on the changes in climate along a northeast-southeast axis; stations at similar elevations have similar annual mean temperature and precipitation normals. The mean area annual rainfall is approximately 1.36 meters (53.5 inches), and the mean temperature is 14.4 degrees C (57.9 degrees F). Precipitation is predominantely in the form of rainfall, although snowfall is occasionally a significant contributor. The annual precipitation pattern is characterized by wet winters and comparatively dry springs followed by relatively wet summers and dry autumns. July rainfall O0.15 meter (5.9 inches)o normally approaches that of the wet winter months, but June rainfall O0.081 meter (3.2 inches)o is as dry as the autumn months. Table A-4 presents the Oak Ridge area summary temperature and precipitation data.

Intense localized weather consists mainly of severe thunderstorms in warm seasons and large-scale storms in the winter. Remnants of hurricanes, weakened by loss of moisture, occasionally affect the area. Between 1953 and 1974, 54 tornadoes occurred within the 10,000 square-mile site area (Project Management Corporation 1977). There were 15 reports of hail, 0.019 meter (0.75 inch) diameter or greater, and 46 reports of windstorms with speeds of 93 kilometers per hour (50 knots) or greater within the one-degree latitude-longitude square Oapproximately 99 by 118 kilometers (62 by 74 miles)o of the site during the period 1955 through 1967. During the period 1971 through 1973, four tropical storms or hurricanes passed within 80 kilometers (50 miles) of the area. Freezing precipitation can be expected about five times each year, and a severe ice storm Oaccumulation of 0.021 meter (one inch) or moreo, once every five years. High air pollution potential can be expected on seven days annually.

A.4.3 Local Wind Patterns

As previously discussed, the local area and the region experience a largely bimodal wind direction pattern that consists of up-valley and down-valley flows. The stability characteristics of these two directional channels are also nearly identical and represent the critical dispersion conditions. It is likely, however, that the similar flows are caused by differing meteorological phenomena (USDOC 1960). The down-valley draft, identified with drainage of gravitational flow down local slopes and the broader Tennessee Valley, prevails during the inversion conditions of late evening through midmorning, at which time regional pressure patterns dependent on solar inputs are very weak. However, in the daytime up-valley flow results when the regional flows aloft become sufficently strong to dominate over the opposing flows. Since these higher altitude regional winds do not exert as pronounced an influence on valleys, the local valley wind regime can even maintain its structures and flow in a direction opposite to that of the regional wind. A normally quoted average wind speed for Oak Ridge of seven kilometers per hour (4.4 miles per hour) is the mean value of annual measurements taken over a 16-year period at the Oak Ridge city office. Inversion conditions occur about one-third of the time throughout the year. This type of vertical temperature distribution occurs primarily as a diurnal response to radiative and convective heat transfers at the earth's surface, but may be secondarily modified by both seasonal solar energy input and cloudiness. A relatively high potential for significant air pollution results.

A.4.4 Wind and Stability Class

All-season area wind-rose data are presented in Figure A-8. The data were assembled from 107,000 observations taken over a period of 12-1/4 years (Hilsmeier 1963). Seasonal differences in the wind data are insignificant; area wind data are tabulated in Table A-5 (Project Management Corporation 1977).

Pasquill stability-class data for the ORNL area are summarized below.

Pasquill Stability Class	Definition of Class	Fraction of Year Each Stability Class
A	Extremely unstable conditions	0.07
B	Moderately unstable conditions	0.14
C	Slightly unstable conditions	0.13
D	Neutral conditions	0.28
E	Slightly stable conditions	0.20
F	Moderately stable conditions	0.14
G	Extremely stable conditions	0.04

Source: W. F. Hilsmeier, Supplementary Meteorological Data for Oak Ridge, ORO, Atomic Energy Commission, Division of Technical Information, Office of Technical Services, Department of Commerce, Washington, D.C., 1963.

A more detailed summary of wind speed and direction data has been prepared by the Atmospheric Turbulence and Diffusion Laboratory of the National Oceanic and Atmospheric Administration, Oak Ridge, Tennessee and includes Oak Ridge Gaseous Diffusion Plant (ORGDP) observations over a period of 13 years, as noted in Table A-6 (ATDL 1972). The National Oceanic and Atmospheric Administration has operated the ORGDP meteorological observation program at Oak Ridge for more than 20 years. The peak gust (wind velocity) of record was 95 kilometers per hour (59 miles per hour) during this period. Calm conditions prevailed approximately 10 percent of the time, partly cloudy 25 percent and cloudy 45 percent.

A.4.5 Tornadoes

A study of tornado occurrences in Tennessee (Vaiksnoras 1971) indicates that the incidence of this type of storm in the Oak Ridge area is quite rare. This is primarily due to the presence of the Cumberland Mountains to the west and the broken terrain in the vicinity. However, numerous tornadoes have been reported in the broad valleys southwest and northeast of the area (Figure A-9). A total of 49 individual tornadoes with track lengths of 25 kilometers (15 miles) or larger occurred in

Tennessee from 1916 to 1970 (Vaiksnoras 1971). As Figure A-9 indicates, most of these were confined to the central and western portions of the state. Based on a relationship developed by the U.S. Weather Bureau (Thom 1963), the expectation that a tornado would strike a given point in the vicinity of ORNL is approximately once in 27,400 years or a probability of 3.65×10^{-5} per year, (Boyle, et al. 1978).

On May 2, 1953, at approximately 3:30 a.m., a small tornado passed through the Oak Ridge Reservation. However, this is the only recorded case of such a storm on the reservation since it was established and no damage was sustained.

A.5 HYDROLOGY

A drainage basin hydrologic cycle can be visualized as inputs of precipitation being distributed through a number of storages by transfer mechanisms, culminating in outputs via channel runoff, evapotranspiration and outflow as groundwater. Variations in annual runoff result from variations in rainfall and rates of water loss. Within the Oak Ridge area, greatest runoff occurs during the period of January, February and March and the least during the quarter of July, August and September (Figure A-10). The average quarterly runoff from the area, as a precentage of annual runoff, is as follows: October-December (17 percent), January-March (49 percent), April-June (23 percent) and July-September (11 percent). The mean annual precipitation is 1.3 meters (51.2 inches) and the average annual runoff, exclusive of Clinch River, is approximately 0.57 meter (22.3 inches). Based upon these data, on the average, runoff accounts for approximately 43.6 percent of precipitation. The annual water loss by evaporation and transpiration was about 0.76 meter (30 inches) or about 55 percent of annual rainfall (McMaster 1967). Evaporation and transpiration losses are greatest during the July-September quarter when at least 80 percent of precipitation is lost.

Additional data and information on streamflow and storm runoff in the Oak Ridge area can be found in McMaster 1967, Sheppard, Speer and Gamble 1964 and Tennessee Valley Authority 1959.

Principal surface drainage of the ORNL (X-10) site is through White Oak Creek and its tributaries. The basin has a drainage area of approximately 16.5 square kilometers (6.5 square miles) and the main channel has a length of approximately four miles. White Oak Creek originates on the forested slopes of Chestnut Ridge a short distance northeast of ORNL. Numerous springs provide a large portion of the discharge in this portion of the catchment.

Approximately 2.4 kilometers (1.5 miles) from the source, the creek enters ORNL and receives a significant discharge contribution in the form of waste water. Melton Branch drains about 3.8 square kilometers (1.5 square miles) in Melton Valley and joins White Oak Creek about 2.4 kilometers (1.5 miles) above the junction with Clinch River (Figure A-11). Before entering the Clinch River, White Oak Creek flows into White Oak Lake, a 20-acre body of water impounded by an earthen dam constructed to regulate the dispersion of radio nuclides and chemical pollutants discharged from ORNL. Below the dam, release water flows for approximately one kilometer (0.6 mile) to the Clinch River. The channel area below the dam resembles a large mud flat and is a site of active erosion-sedimentation activities depending upon water levels in the Clinch River resulting from release patterns at Melton Hill and Watts Bar Dams. During times of high stage on the Clinch, backwater extends up White Oak Creek to White Oak Dam and completely drowns out the normal channel.

Some discharge data are available for this watershed. Webster 1976 summarized data on White Oak Creek and Melton Branch at three sites. On White Oak Creek one-tenth mile above Melton Branch, the average, minimum and maximum discharges for 10 years of record (1950-52, 1955-63) were 0.273, 0.054 and 18.2 cubic meters per second (9.62, 1.9 and 642 cubic feet per second) respectively. For Melton Branch 0.16 kilometer (one-tenth mile) above White Oak Creek, the average, minimum and maximum values for the period 1955-63 were 0.071, zero and 6.86 cubic meters per second (2.50, zero and 242 cubic feet per second). At White Oak Dam for the period 1953-55 and 1960-63, these values were 0.382, zero and 19.0 cubic meters per second (13.5, zero and 669 cubic feet per second). Additional data, including daily flow duration values (Table A-7) for Melton Branch and White Oak Creek, are given by McMaster 1967. About 90 percent of White Oak Creek dry-weather flow results from groundwater discharge and ORNL plant effluent.

Groundwater

In the Oak Ridge area, the Knox dolomite and the Chickamauga limestone are the principal aquifiers. The Rome Formation and Conasauga Group probably do not contain significant quantities of groundwater. The Knox, located beneath Chestnut Ridge, is the major aquifer in White Oak Creek basin. The thick, weathered mantle seems to have a high infiltration capacity and serves as a reservoir feeding large solution cavities in the bedrock. Springs at the base of Chestnut Ridge are the primary natural source of base flow for White Oak Creek. Groundwater discharge from the Knox beneath Copper Ridge is probably not into White Oak Creek Basin but instead to the southeast along the Clinch River. Depth to the Knox water table in Chestnut Ridge is at a maximum of 38 meters (125 feet) at the ridge crest (McMaster and Waller 1965).

Most openings in the Chickamauga are only a few tenths of a meter in diameter because of the limestone's more thinly bedded, shaly characteristics. Additionally, the weathered mantle is primarily heavy clay less than three meters (10 feet) thick; consequently, infiltration and recharge are limited. Undoubtedly, rates and quantities of water movement are relatively small even though a significant quantity of groundwater may be stored in the unit near the surface (McMaster and Waller 1965).

In the siltstones and shales of the Rome Formation and Conasauga Group, water is found only in small openings or partings along joints and bedding planes. Because these rocks contain little calcium carbonate and thus are relatively insoluble, these openings have not been enlarged significantly (McMaster 1967).

A detailed review and examination of groundwater and geologic conditions at ORNL and their relation to radioactive waste disposal was recently published by in Webster 1976. Local groundwater conditions at several locations in White Oak Creek watershed are presented in Webster's report.

Depth to the water table varies both spatially and temporally. At a given location, depth to water is generally greatest during the October-December quarter and least during the quarter January through March (see McMaster 1967). In Bethel Valley depth to water table ranges from 0.3 to 10 meters (one to 35 feet) whereas in Melton Valley the range is from 0.3 to 20 meters (one to 67 feet) (Webster 1976). Seasonal fluctuations tend to be greatest beneath hillsides and near the groundwater divide. As much as 4.5 meters (15 feet) seasonal variation was reported in Webster 1976 for Melton Valley.

Water-table contour maps are useful, in a general way, for estimating the direction of groundwater movement, especially in the weathered residuum or unconsolidated materials overlying bedrock. However, direction of movement in the underlying strata is influenced more strongly by directional variations in permeability. Groundwater flow in the residuum is generally toward the individual channels of the surface-drainage network. In Bethel Valley, groundwater in the Chickamauga limestone moves through small solution channels. Direction of movement is complex and controlled by the three-directional geometry and degree of interconnection of the solution openings. There is no reported evidence indicating subsurface movement from the X-10 area of Bethel Valley to adjacent drainage basins (Webster 1976).

Groundwater movement in the Conasauga of Melton Valley has been considered in four separate investigations (see Morton, et al. 1954; Struxness 1955; Cowser and Parker 1958; De Laguna, et al. 1958; Lomenick, et al. 1964; Lomenick, et al. 1967). Each investigation concluded that within the study area, the primary direction of groundwater movement in the Conasauga is parallel to strike. This observation suggests that greatest permeability is unweathered bedrock, and is associated with partings between beds and perhaps with residue of more soluble units. However, Webster reported that factors controlling fluid movement within the Conasauga vary with depth. He concluded that in the uppermost portion of the saturated zone, the slope of the water table (hydraulic gradient) is the primary factor controlling movement. With increasing depth, there is a change in control from the areal hydraulic gradient to control by local hydraulic head distribution within the partings, joints, fractures, or other more permeable zones within the rock. Webster also reported that the rate of movement in limestone beneath Bethel Valley is relatively slow because of the small size of solution cavities observed in drill cores and the slow recovery of wells after pumping (see De Buchananne in Stockdale 1951). The best current estimate of movement rate in the Conasauga under natural conditions is about 0.17 meter per day (0.56 feet per day) along strike for the first five feet and only slightly less than this out to a distance of 10 feet (Lomenick 1967).

Floods

From an investigation of flood magnitude and frequency in the Cumberland and Tennessee River basins, Speer and Gamble 1964 reported that for the hydrologic area including Oak Ridge, stream discharge as high as 370 cubic meters per second (13,000 cubic feet per second) can occur on watersheds as small as 3.8 square kilometers (1.5 square miles). For further information on flood discharges in the Oak Ridge area, the reader is referred to Sheppard 1974 and Lesesne 1979.

A.6 ECOLOGY

The Oak Ridge Reservation is typical of the ecological systems which occur in the Appalachian Region of the eastern United States. A preliminary inventory of the vegetation of the Oak Ridge area was compiled by Olson, et al. 1966. This listing has subsequently been supplemented with observations of spring flowering of 171 species of herbaceous and woody plants from 55 different families (Taylor 1969).

Seven vegetation types have been identified on the Oak Ridge Reservation (USERDA 1975).

1. Yellow Pine/Yellow Pine-Hardwoods. This is presently the most extensive type on the reservation. These areas are dominated by short-leaf and Virginia pine in association with large tracts of planted loblolly pine. Associated species in the natural succession forests include oaks, hiskories and tulip poplar.

2. Hemlock and/or White Pine/Hemlock and/or White Pine with Hardwoods. This type represents a Southern Appalchian extension of a northern, higher elevation forest and is extremely restricted in occurrence. Hemlock and white pine dominate.

3. Cedar and Cedar Pine/Cedar-Hardwoods. An extensive type predominating in Bethel Valley and areas close to the Clinch River. The dominant species is eastern red cedar associated with shortleaf and Virginia pine, tulip poplar, oaks, hickories, redbud, sassafras and other hardwoods.

4. Bottomland Hardwoods. This vegetation type is restricted to floodplain-creek bottom areas. Dominant species include cotton wood, sycamore, elm, ash, willow silver maple and river birch.

5. Upland Hardwoods. This type occurs over approximately 20 percent of the reservation area. This forest is essentially an oak-hickory complex representing the terminal type in this geographic region. Important species include chestnut oak, white oak, black oak, northern red oak, scarlet oak, post oak, various hickories and ash, tulip poplar, red maple, black gum, dogwood, beech and others.

6. Northern Hardwoods. This forest type is very rare on the reservation, occurring only in restricted areas on Black Oak and Copper ridges. Composition is similar to the Upland Hardwood type with sugar maple, hemlock, basswood and buckeye also being present.

7. Nonforest. This category includes primarily grasslands, devegetated areas and cultural features. Native or semi-native areas include species of bluestem, fescue and bluegrass.

Three distinct terrestrial animal habitats have been identified on the Oak Ridge Reservation (USERDA 1975; Dahlman, et al. 1977).

1. Hardwood-Mixed Hardwood Habitat. Sporadic sampling of small-mammal populations indicates that six species are common in this oak-hickory, chestnut oak and pine forest type. These are white-footed mouse, eastern chipmunk, golden mouse, short-tailed shrew, flying squirrel and house mouse. Both red and gray fox are common predators. Opossum, raccoon, striped skunk and bobcat inhabit varied areas and roam through upland forest areas. White-tail deer are also found in upland and bottomland forests, and a large number of bird species are also present in this particular habitat.

2. Pine Plantation Habitat. Animal populations of these pine communities have not been sampled extensively. It seems only three small-mammal species use these areas extensively (white-footed mouse, golden mouse and short-tail

shrew). Pine mouse, cotton rat and harvest mouse have also been observed. Large mammals, gray squirrels, opossum, deer and predators probably use this habitat for shelter. Pine warbler and white-throated sparrow appear to be very common but few other birds have been surveyed.

3. Old-Field and Grassland Habitat. Cotton rats, white-footed mice, golden mice, rice rats, short-tailed shrews and eastern harvest mice have been trapped in this habitat. Some game birds, such as quail and raptorial species use these areas as do sparrows, towhees, blue grosbeaks and other field species of birds.

The herpetofauna of the area have been described and habitat types categorized (Johnson 1964). Various species of salamanders, turtles, frogs, toads, lizards and snakes have been identified.

The Clinch River provides an aquatic habitat typical of the area. Submergent plants include Potamogeton, Chara, Najas, Elodea and Myriophyllum (Milfoil). Phytoplankton samples indicate diatoms, dinoflagellates, blue-green algae, euglenoids and green algae are present. Communities of zooplankton, composed primarily of Rotifera species, exist in slow water areas of Melton Hill Reservoir and backwater areas of the Clinch and tributary streams. Samples of benthic macroinvertebrates indicate the presence of Corbicula clams, the oligochaete Najas, Chironomidae, annelids, arthropods (insects and crustaceans) and coelenterates. Hydra is the dominant organism. Predominant fish species in the Clinch River adjacent to the reservation are gizzard shad, threadfin shad, skip-jack herring, carp, smallmouth buffalo, white bass, white crappie, sauger and freshwater drum (USERDA 1975).

It should be noted that fisheries resources of the Tennessee River system are utilized by both sport and commercial fishing activities. Some commercially harvested species (for example carp and buffalo) are sold for human consumption. Records of commercial harvests from the Tennessee River for the period 1946-1963 range from a low yield of 487,700 kilograms (1,073,000 pounds) in 1947 to a high of 3,878,000 kilograms (8,532,000 pounds) in 1963. These takes were comprised mainly of catfish and buffalo (Clinch River Study Steering Committee 1967).

White Oak Lake has been described as having high phytoplankton productivity and a well developed benthic fauna, with various insect larvae being the most common forms (Kolehmainen and Nelson 1969). Fishes present in the shallow embayment include bluegill and redear sunfish, largemouth bass, warmouth, gizzard shad, golden shiners, goldfish and mosquitofish (USAEC 1974).

A listing of typical habitat types of 212 animal and bird species of the Oak Ridge Reservation can be found in USERDA 1975. Dahlman, et al. 1977 have tabulated an extensive list of species found in different aquatic habitats on the Reservation. Additional information regarding the ecology, flora and fauna of the Oak Ridge area may be found in Anderson and Shugart 1974; Kitchings and Mann 1976; Krumholtz 1954 (a, b and c) and Mann and Bierner 1975.

Rare and Endangered Plants

Two plant species have recently been found on the DOE reservation which are on the *Federal Register* list of threatened or endangered plants (Parr and Taylor 1978). These are *Cimicifuga rubifolia* (Ranunculaceae) and *Saxifraga careyana* (Saxifragaceae). *Conradina verticillata* (Lamiaceae) have been recorded from nearby Morgan County (Kitchings and Mann 1976) and could possibly occur on the reservation. Sixteen species have been identified as rare on the reservation, but all are locally abundant within the state of Tennessee.

Rare and Endangered Animals

The southern bald eagle (*Haliaeetus l. leucocephalus*) and the eastern cougar (*Felis concolor cougar*) have both been sighted on the reservation. Both are endangered. The endangered Indian bat (*Myotis sodalis*) has been recorded from nearby Campbell County, Tennessee, and suitable habitat exists on the reservation; none has been sighted, however. The American osprey (*Pandion haliaetus carolinensis*) is included in the Audubon Blue List and has been seen on the reservation.

Endangered Species

None of the fish species collected in the ORNL sampling programs are designated as endangered under the Endangered Species Act of 1973.

Water Quality

Water analyses from five stations on White Oak Creek and Melton Branch are summarized for 1970 and 1971 in Tables A-8 and A-9. Water quality data measured in 1975 and 1976 at White Oak Dam are presented in Table A-10.

Upstream from ORNL, White Oak Creek is a small, clear, hardwater stream of good water quality. Phosphate, nitrate and heavy-metal concentrations are generally low. Laboratory discharges, leachates and drainage from water disposal areas combine to render the stream significantly poorer in quality in the lower reaches of the waterway.

Concentrations of Sr-90, Cs-137, Ru-106, and H-3 at the confluence of White Oak Creek and the Clinch River are presented in Table A-11 for 1976. These values are calculated values based on the concentrations measured at White Oak Dam and the dilution afforded by the Clinch River. The yearly average dilution for 1976 was 422. Radioactive materials (e.g., fallout) that may enter the Clinch River upstream of the White Oak Creek outfall are not included in this calculation.

A.7 HUMAN ENVIRONMENT

A.7.1 Historical Background

The Oak Ridge Reservation was originally purchased for nuclear production and research with surrounding security and safety buffer areas. Originally 240 square kilometers (59,000 acres) were acquired in 1942, but the area has been reduced subsequently to approximately 150 square kilometers (37,000 acres) through land transfers to municipal government and to state and Federal agencies (Curlin 1965).

A.7.2 Demography

Oak Ridge National Laboratory (X-10) is part of the DOE reservation located in Anderson and Roane counties. Five counties surround the site: Anderson, Knox, Loudon, Roane and Morgan. The combined population of the five counties in 1979 was 413,359; most of the population (336,593) was located to the east of the site in Anderson and Knox counties. The 1975 estimated population for the five counties was approximately 437,000 a six percent increase since 1970. Figure A-12 shows all communities with a population greater than 1,500 within a 100-kilometer (62-mile) radius of the reservation.

The populated area of Oak Ridge begins approximately five miles north of the X-10 site and the city limit of Knoxville, the largest city in the area, is approximately 21 kilometers (13 miles) east of the site. Oak Ridge population was approximately 28,000 in 1970 whereas that of Knoxville was approximately 175,000. There are 21 urban centers of 1970 population over 2,500 (Table A-12) and 27 centers with population less than 2,500 (Table A-13) within an 80-kilometer (50-mile) radius. Other 1970 census data indicate a total population of 678,000 within an 80-kilometer (50-mile) radius which yields a population density of 33 people per square mile. The projected population for this same area for the year 2000 is 899,281 and a population density of 44 people per square mile. The total population within a 100-kilometer (70-mile) radius is reported to have been 1,025,864 in 1970, (USAEC 1974).

A.7.3 Land Use

Land use on the Oak Ridge Reservation has changed with time. Aerial photographs taken in 1942 indicate that approximately 43 percent of the area was comprised of fields and pasture, and the remining areas were forested. In 1947, a reforestation program was begun to replace timber harvested for construction of the Oak Ridge facilities and as a land management action. This program ended in 1960 after approximately nine-million pine seedlings had been planted in old fields and open areas. By 1965 approximatley 4,300 acres of shortleaf, loblolly and eastern white pine plantations were contained within the Reservation (Curlin 1965).

The present allocation of Reservation land use among the plant installations is: Research and Management 41 percent, ORNL 24 percent, Y-12 10 percent, K-25 15 percent and UT-DOE 10 percent (USAEC 1974). Buffer areas around each facility provide increased security and protection against accidental release of toxic materials as well as providing room for future expansion. Excluding the buffer areas, the remainder of the reservation is subdivided into 24 management units ranging in size from 1.6 to 4.9 net managable square kilometers (Curlin 1965). Approximately 93 percent of the total manageable land is forested in pine (36 percent), upland hardwoods (32 percent), mixed pine hardwoods (21 percent) and cedar and miscellaneous species (11 percent) (USAEC 1974).

In 1975, Oak Ridge Operations, U.S. Energy Research and Development Administration published a land-use plan for the Oak Ridge Reservation. This document, USERDA (1975) contains detailed and categorical information on land and water resources, facilities, current usage and both firm and tentative future commitments for land use on the Reservation.

Natural Resources: Very little information is readily available with which to assess the natural resources of the Oak Ridge Reservation and the immediate surrounding area. The Oak Ridge area is located within the Tennessee Valley and, as a consequence, water is abundant and an important natural resource. The system of reservoirs on the Tennessee River and its principal tributaries are multi-purpose and many are in close proximity to the DOE facilities. Aside from providing water for domestic and industrial use, these reservoirs provide recreational facilities for the local population. Fishing, boating, swimming and other forms of water and outdoor recreation activities are available. In addition, many dams are used for electric power generation. Melton Hill Reservoir is located along the southern and eastern boundary of the Reservation and Norris Dam is only a few miles upstream on the Clinch River.

Agricultural productivity of the soils in the area is quite variable. The potential for productivity is based upon the physical and chemical characteristics of the soil and on conservation and topographic features of the landscape. Usually soils are ranked into five classes with first-class soils being the most productive (Swann, et al. 1942). These soils classes provide a basis for summarizing land-use potential for agriculture as follows:

Type 1 - Land is favorably productive, workable and has minimal conservation problems. This type includes first-, second- and third-class soils. Approximately 15 percent of the land of the Oak Ridge Reservation falls within this category.

Type 2 - Land characterized by moderate productivity but unfavorable workability. Frequent conservation problems are encountered; fourth-class soils make up this land type. Approximately 35 percent of the reservation is included in this category.

Type 3 - Fifth-class soils, suitable only for forestry, comprise this land type. Approximately 50 percent of the reservation falls in this group (USERDA 1975, Dahlman, et al. 1977).

The potential exists for some mineral resources in Anderson and Roane counties. This is largely determined by local geologic conditions, especially the lithologic and chemical characteristics of stratigraphic units. Carbonate rocks (limestone and dolomite) can be economically important as sources of crushed stone, agricultural limestone, lime, cement and dimension stone. Some shales can also be used for brick and lightweight aggregate manufacture, and certain sandstones can be quarried for dimension stone. The suitability of local bedrock for industrial usage depends not only upon physical and chemical rock characteristics, but also upon surrogate sources in the surrounding area, ease of extraction, external supply and many other economic considerations. Rock quarries are present in the Oak Ridge area and large quantities of coal are mined in the Cumberland Mountains area to the west. Additional, detailed information on the mineral resources of the Reservation and its environs is lacking. However, one could conjecture that they are relatively minor in occurrence and economic contribution.

Maher 1973 summarized the mineral resources of Knox County and reported $23.9 million of mineral production for the county in 1970. Even though geologic conditions are similar between Knox, Anderson and Roane counties, mineral resource comparisons would be very difficult because of local geologic, physiographic, economic, industrial and demographic variations. Additional information on the mineral resources of the Oak Ridge area may be present in publications by the U.S. Bureau of Mines and the Tennessee Division of Geology.

Transportation: Major highways include Interstate 40 about 1.5 kilometers (one mile) south of the reservation and Interstate 75 about 3.2 kilometers (two miles) southeast of the reservation. State Highways 95, 58 and 62 pass through or adjacent to the reservation.

The closest major main rail line is Harriman Junction, about 16 kilometers (10 miles) to the west. It is served by both the Cincinnati, New Orleans and Texas Pacific (CNO & TP) Railway and the Southern Railway.

Only one airport (Oak Ridge Air Park) is within 16 kilometers (10 miles). No commercial air routes pass over the reservation. Airports near the site are:

Meadowlake	-	sport
Oak Ridge Air Park	-	sport
Rockwood Municipal	-	business/sport
McGhee-Tyson	-	commercial

Only McGhee-Tyson (Knoxville) located over 40 kilometers (25 miles) from the site has scheduled commercial flights.

The Clinch River (Melton Hill Reservoir) adjacent to the ORNL property is a component of the Inland Waterway System, which allows commercial navigation to the Gulf of Mexico. Commercial traffic locked through Melton Dam amounted to 2,720 metric tons (3,000 tons) in 1975. In 1974, 631 recreational craft passed through Melton Hill locks.

Military Facilities: There are no military facilities or bases within 16 kilometers (10 miles) of the reservation.

A.7.4 Water Use

Major water uses in the vicinity of ORNL include water withdrawals for industrial and public water supplies, commercial and recreational water traffic and other recreational activities such as swimming and fishing.

Major water withdrawals from the Clinch River are for DOE Oak Ridge Operations, the city of Oak Ridge and DOE TVA Bull Run Steam Plant and West Knox Utility District.

Groundwater use (wells) within an approximate 32-kilometer (20-mile) radius includes not only industrial and public water supplies but also a large number of small-capacity individual and multiunit domestic wells.

The Clinch River is the major groundwater sink for the area. Discharge from the aquifer system at ORNL flows directly into the river or its tributaries (i.e., Melton Branch, White Oak Creek). Because the incised meander of the Clinch River is a major topographic feature set in bedrock, it is unlikely that a significant groundwater flow passes beneath the river. No groundwater wells are located where they could potentially intercept seepages from the site before discharge into the Clinch River system.

Recreational use of the lands and waters in the Oak Ridge region is heavy (see Subsection A.7.3). Although no quantification of recreational use such as swimming, fishing and localized recreational boating is available, a large proportion of these recreational areas are located along waterways, and frequent recreational interactions with water are assumed.

A.7.5 Regional Landmarks

A.7.5.1 History

Among the early settlers in what is now the Oak Ridge Reservation were William Tunnell, Anne Howard, Isaac Freels and Collins Roberts. The descendants of these families were still in the area when the Corps of Engineers acquired the land for the Manhattan Project in 1942. Many current place names on the reservation, such as Freels Bend and Robertsville, were derived from these early settler families (Fielder 1974).

A grist mill existed on the east fork of Poplar Creek before 1796 when Tennessee was still a part of North Carolina. Walker's Mill was built where the east fork empties into Poplar Creek near the present site of the Oak Ridge Gaseous Diffusion Plant (Young 1975).

Sparsely written history of the area indicates that a Methodist Church existed in the early days of settlement. Mt. Zion Baptist Church was founded in the early 1850's, and Cumberland Presbyterian Church followed along with George Jones Memorial Baptist Church, the only structure left in the group (Young 1975).

Also located in the area at the time of the 1942 acquisition by the U.S. Government were the East Fork Masonic Lodge, Robertsville School, Wheat High School, Adam's Store and Post Office and many clapboard houses and log cabins. A ferry existed at the present Gallaher Bridge site until the late 1930's.

A research team from the Department of Anthropology, University of Tennessee, Knoxville, conducted an archaeological survey (Fielder 1975), of the proposed gas centrifuge plant site at the western end of the Oak Ridge reservation adjacent to Oak Ridge Gaseous Diffusion Plant. The purpose of the survey was to locate, inventory and evaluate the prehistroic and historic cultural resources in the proposed impact area. One conclusion was that there are no historic structures or sites that require preservation or mitigation of adverse impact under the criteria of the National Register of Historic Places.

The only historic site listed in the National Register of Historic Places in the Oak Ridge area is the Graphite Reactor Building at Oak Ridge National Laboratory. Constructed during World War II as part of the Manhattan Project, the Graphite Reactor is the world's oldest existing nuclear reactor and is now open to the public on a routine basis.

A.7.5.2 Archaeological

An earlier archaeological survey (Fielder 1974) of the Oak Ridge reservation was conducted by the Department of Anthropology, University of Tennessee, Knoxville, from March 15 to June 30, 1974. Sites of aboriginal occupation that might be affected by future activities on the reservation were located and evaluated.

Reconnaissance and testing were done in several different physiographic zones, including the Clinch River and its larger tributary-stream terraces, the interior valleys, selected forested ridges and specific facility areas. Previously recorded sites, known but unrecorded sites and previously unknown sites were investigated. The survey techniques included collecting surface artifactual materials, examining subsurface soil strata and interviewing longtime residents and employees.

In total, 45 sites of aboriginal occupation and several early historic Euroamerican homestead sites are described. Several locations were found on Popular Creek, East Fork Poplar Creek and White Oak Creek. Only one site (40RE132) is located in White Oak Creek watershed above White Oak Dam. This is in the area of Burial Ground 6, and much of the site was apparently destroyed during excavation and disposal operations. A total of 204 artifacts were recovered at the site. One other site (40RE131) is located adjacent to White Oak Creek below the dam while a second (40RE27) is located near the confluence of White Oak Creek with Clinch River. None of these sites appear to be of special significance or interpretative value (Fielder 1974).

A.7.5.3 Cultural

The tremendous diversity of interests and activities of Oak Ridgers is indicated by the number of organizations (nearly 300 currently) listed each year by the local newspaper. The Oak Ridge Music Association schedules nationally known musicians during the fall and winter seasons. These performances are interspersed with concerts by the Oak Ridge Symphony Orchestra and the Oak Ridge chorus, both directed by a professional conductor. In Knoxville, the University of Tennessee's University of Concerts series brings Broadway shows, ballet companies and noted personalities to the Knoxville Municipal Coliseum and Auditorium.

The Oak Ridge Art Center houses a gallery, a studio and gift shop. Both local and traveling art shows are on display almost continually at the Center, and courses are offered in ceramics, lithography, oils, watercolors, drawing and sculpture.

The American Museum of Atomic Energy is a major attraction for tourists in eastern Tennessee. The $3.5 million building features models, movies, demonstrations, devices and machines, all designed to describe and explain concepts relating to energy phenomena.

Another point of interest is the University of Tennessee Arboretum, which includes one of the southeast's largest and most complete collections of trees and plants from the Appalachian region and serves as a living source of information about trees and shrubs.

A.7.5.4 Scenic

Oak Ridge is situated in the middle of scenic East Tennessee, surrounded by mountains, rivers, lakes and heavily forested ridges. Within an hour's driving distance of Oak Ridge are five of the 22 reservoirs built by the Tennessee Valley Authority on the Tennessee River and its tributaries. These five reservoirs have a total shoreline of 3,700 kilometers (2,320 miles) and with other lakes and streams provide fishing, boating, swimming and other water sports.

Oak Ridge is about 100 kilometers (60 miles) from the nation's most visited national park, the Great Smoky Mountains.

Oak Ridge has four city-maintained parks: Chestnut Ridge (off of Melton Lake Drive), Ridgewood Park (near the Municipal Building), Key Springs Park (off of Outer Drive) and Scarboro Village Park (in the Scarboro community). In addition to municipal parks, Clark Center Park, developed by Union Carbide Corporation for its employees, offers boating, swimming and other facilities.

A substantial part of the land in and around Oak Ridge is undeveloped. Currently there are about 510 hectare (1,260 acres) in city-owned and an almost equal amount in institutionally owned open space. Open space in the urban area can be attributed partly to pockets in residential developments left open due to rough terrain; green belts along the urban fringe provide additional natural surroundings.

A.7.6 <u>Socioeconomics</u>

The development and operation of the DOE installations (previously the Manhattan Project, U.S. AEC and ERDA) have greatly influenced the socioeconomic character of the region. The plants have recruited numerous workers from outside the region, created long-term permanent employment for many local citizens, contributed to the development and growth of towns and cities and affected the operation of a variety of social and political institutions.

Employment in the atomic energy program at Oak Ridge is divided among DOE (prior to February 1975, the Atomic Energy Commission; from February 1975 to October 1977, ERDA) and its principal operating contractors: Union Carbide Corporation-Nuclear Division (UCC-ND), which operates the Oak Ridge Gaseous Diffusion Plant (ORGDP), the Oak Ridge Y-12 Plant, and the Oak Ridge National Laboratory (ORNL); Oak Ridge Associated Universities (ORAU); and the University of Tennessee, which operates the Comparative Animal Research Laboratory (CARL). In 1976, these installations employed an average of 17,400 persons distributed among the installations as shown in Table A-14.

Overall, the three major installations operated by UCC-ND under contract with DOE have provided a rather stable source of employment of 30 years, averaging about 13,000 employees annually (Table A-15). These figures do not include the people employed to construct the plants; at the peak construction period in mid-1945, an estimated 70,000 workers were involved in the construction of the three plants. Since 1973, total employment at the three plants has grown substantially (by about 4,000 workers); however, of the three plants only ORNL and ORGDP have actually expanded.

In recent years, less than half of the work force resided in Oak Ridge; for example, in 1975, 34.6 percent lived in Oak Ridge, 21.4 percent lived in Knoxville and the remaining 44 percent lived in the surrounding counties or in smaller outlying towns and communities (Table A-16).

The impact of geographical distance and access on residence location of employees is not easily discernible from data available (Table A-17). With respect to ORGDP personnel, there is a slightly higher probability for them to live in Kingston or Harriman than for employees of ORNL and ORGDP, a situation suggesting that occupational classification is probably a better indicator of residence location than is geographical distance to the plant.

TABLE A-1 GENERALIZED GEOLOGIC SECTION OF BEDROCK FORMATIONS IN OAK RIDGE AREA

System	Group	Formation	"Member" or Unit	Thickness (feet)	Characteristics of Rocks
Mississippian		Ft. Payne "chert"			Impure limestone and calcareous siltstone, with much chert
	?	Chattanooga shale			Black, fissile
Devonian					
Silurian	Rockwood	Brassfield		1,000+	Shale, sandy shale, sandstone; calcareous; red, drab, brown
		Sequatchie			
Ordovician	Chick-amauga		?		Limestone, shaly limestone, calcareous siltstone and shale; mostly gray, partly maroon; with cherty zones in basal portions
			H	300+	
			G	300	
			F	25	
			E	380	
			D	160	
			C	115	
			B	215	
			A	240	
	Knox			2,600	Dolomitic limestone; light to dark gray; with prominent chert zones
Cambrian	Conasauga	Maynardsville limestone		1,500	Shale; gray, olive-drab, brown; with beds of limestone in upper part
		Conasauga shale	Pumpkin Valley		
		Rome		1,000+	Sandstone and shale; variegated with brilliant yellow, brown, red, maroon, olive-green; with dolomitic limestone lenses

TABLE A-2 ANNOTATED LIST OF EARTHQUAKES THAT HAVE AFFECTED OAK RIDGE RESERVATION OR EASTERN TENNESSEE VICINITY

Date	Geodetic Coordinates (°N)	Geodetic Coordinates (°W)	Epicenter Area	Maximum MM Intensity at Epicenter	Estimated MM Intensity at Oak Ridge	Notes
1811, Dec. 16	36.6	89.6	New Madrid, Mo.	XII	V-VI	Strongest shocks of a great series collectively known as New Madrid Earthquake.
1812, Jan. 23	36.6	89.6	New Madrid, Mo.	XII	V-VI	Topographic changes effected over an area of 3,000-5,000 square miles in Mississippi Valley.
1843, Jan. 4	35.2	90.0	Western Tenn.	VIII	III-IV	Shock felt over 12 states, including entire Tennessee Valley.
1844, Nov. 28	36.0	84.0	Knoxville, Tenn.	VI	V	25 miles from Oak Ridge area.
1861, Aug. 31	36.6	78.5	Virginia	VI	III-IV	Described as "heavy shock" in Oak Ridge area.
1886, Aug. 31	32.9	80.0	Charleston, S.C	IX-X	V-VI	Great Charleston Earthquake felt over entire eastern U.S.
1895, Oct. 31	37.0	89.4	Charleston, Mo.	XI	III-IV	Shock felt over 23 states, including entire Tennessee Valley.
1897, May 31	37.3	80.7	Giles County, Va.	XII	III-IV	Shock felt throughout east Tennessee. Heaviest shock in historic time in southern Appalachia.
1902, May 29	35.1	85.3	Chattanooga, Tenn.	V	?	Not reported to have been felt in Oak Ridge area.
1902, Oct. 18	35.0	85.3	Chattanooga, Tenn	V	?	Not reported to have been felt in Oak Ridge area.
1904, Mar. 4	35.7	83.5	Maryville, Tenn.	V	II-III	Low intensity except at epicenter.
1905, Jan. 27	34.0	86.0	Gadsden, Ala.	VII	II	Large "felt" area, but probably very low intensity shock.
1913, Mar. 28	36.2	83.7	Strawberry Plains, Tenn.	VII	V-VI	One of strongest shocks in southern Appalachia.
1913, Apr. 17	35.3	84.2	Ducktown, Tenn.	V	?	Not reported to have been felt in Oak Ridge area.
1914, Jan. 23	35.3	84.2	Southeastern, Tenn.	V	?	
1916, Feb. 21	35.5	82.5	Asheville, N.C.	VI	III-IV	Only felt reports are from the epicenter, so probably local.
1916, Oct. 18	33.5	86.2	Easonville, Ala.	VII	III	Felt over whole state of Tennessee, especially mountains of east Tennessee.
1918, June 21	36.0	84.1	Lenoir City, Tenn.	V	IV	15 miles from Oak Ridge area.
1920, Dec. 14	36.9	85.0	Rockwood, Tenn.	V	III	35 miles from Oak Ridge area.
1921, Dec. 15	35.8	84.6	Kingston, Tenn.	V	III-IV	Shock of "considerable intensity" only 15 miles from Oak Ridge area.
1924, Oct. 20	35.0	82.6	Pickens County, S.C.	V	II	Large "felt" area, but little effect in eastern Tennessee.
1927, Oct. 8	35.0	85.3	Chattanooga, Tenn.	IV-V	II	Not reported to have been felt in Oak Ridge area.
1928, Nov. 2	35.8	82.8	Madison County, N.C	VII	III	Large "felt" area, including all of eastern Tennessee.
1930, Aug. 30	35.9	84.4	Kingston, Tenn.	V	V	5 miles northwest of Oak Ridge Reservation.
1938, Mar. 31	35.6	83.6	Little Tennessee River Basin	III	I-III	Centered in mountains and felt widely in eastern Tennessee.
1940, Oct. 19	35.0	85.0	Chattanooga, Tenn.	V	?	Not reported to have been felt in Oak Ridge area.
1941, Sept. 8	35.0	85.3	Chattanooga, Tenn.	IV-V	?	Not reported to have been felt in Oak Ridge area.
1945, June 14	35.0	84.5	Cleveland, Tenn.	V	II	"Felt" area over southeast Tennessee and northwest Georgia.
1946, Apr. 6	35.2	84.9	Cleveland, Tenn.	III	?	No reports of shock outside of city.
1947, Dec. 27	35.0	85.3	Chattanooga, Tenn.	IV	?	Not reported to have been felt in Oak Ridge area.
1954, Jan. 1	36.6	83.7	Knoxville, Tenn.	V-VI	IV-V	Large shock area including all of eastern Tennessee; no damage at Oak Ridge.

TABLE A-2 ANNOTATED LIST OF EARTHQUAKES THAT HAVE AFFECTED OAK RIDGE RESERVATION OR EASTERN TENNESSEE VICINITY

Date	Geodetic Coordinates (°N)	Geodetic Coordinates (°W)	Epicenter Area	Maximum MM Intensity at Epicenter	Estimated MM Intensity at Oak Ridge	Notes
1954, Jan. 22	35.4	84.4	McMinn County, Tenn.	V	?	No reports of shock outside of county.
1956, Sept. 7	35.5	84.0	Corbin, Ky.	VI	IV-V	Two shocks, 14 minutes apart, felt over most of southern Appalachia.
1957, June 23	35.9	84.3	Knox County, Tenn.	V	IV	5 miles from Oak Ridge area.
1959, June 12	35.3	84.3	Tellico Plains, Tenn.	VI	II-III	Widely felt over eastern Tennessee and western North Carolina.
1960, Apr. 15	35.8	83.9	Knoxville, Tenn.	V	IV	20 miles from Oak Ridge area.
1968, Nov. 9	38.0	88.5	Southern Illinois	VII	II-III	Felt over 400,000 square mile area including 23 states and areas of Canada.
1969, July 3	36.1	83.7	Knoxville, Tenn.	V	III-IV	30 miles from Oak Ridge area.
1969, Nov. 19	37.4	81.0	Southern W. Va.	VI	II-III	Large "felt" area but small intensity.
1971, July 12	35.9	84.3	Knoxville-Oak Ridge, Tenn.	III-VI	III-IV	Shock felt with full intensity in Oak Ridge area; no personal injuries or property damage reported.
1973, Oct. 5	35.5	83.7	Maryville, Tenn.	IV-V	III-IV	25 miles from Oak Ridge area.
1973, Nov. 3	35.5	83.7	Maryville, Tenn.	V-VI	IV-V	25 miles from Oak Ridge area.
1975, Feb. 10	36.1	83.6	Knoxville, Tenn.	?	'	Not reported to be felt in Oak Ridge area, 60 miles from Oak Ridge.
1975, May 2	36.07	84.41	Roane County, Tenn.	?	III	10 miles from Oak Ridge area.

Sources:

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   "Part I (1699-1850)," J. Tenn. Acad. Sci. 29(3): 224-233 (1954)
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2. Project Management Corporation, Preliminary Information on Clinch River Site for LMFBR Demonstration Plant, August 23, 1972, pp. 73-82.

3. Following publications of U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service (formerly, U.S. Coast and Geodetic Survey).
   a. United States Earthquakes, 1928-1935 (collected annual reports), No. COM-73-11456 (Reprint)
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   d. United States Earthquakes, 1946-1972 (individual annual reports).
   e. Preliminary Determination of Epicenters, 1972 (monthly listing).
   f. Earthquake History of the United States, Publication 41-1 (Rev. ed. through 1970), Washington, D.C., 1973, pp. 21-58.

TABLE A-3 DISTRIBUTION OF SOIL SERIES OF WHITE OAK CREEK BASIN BY GEOLOGICAL UNIT AND BY SOIL CLASS

Geologic Unit[a]	Soil Series Upland	Soil Series Colluvial	Soil Series Local Alluvial	Geologic Unit by Physiographic Position (%) Upland	Colluvial	Local Alluvial	Occurrence of Upland Soil Series (%)
Ock[b]	Fullerton	Minvaie	Emory	82	10	8	70
	Bodine	Landisburg	Greendale				5
	Claiborne						5
	Kewey						2
Och a[c]	Fullerton			100			80
	Bodine[d]						20
Och b	Bland	Bland		80	20		60
	Colbert	Colbert					20
Och d	Talbott	Leadvale	Leadvale	80	20		35
Och e	Colbert	Hamblen	Hamblen				35
Och f	Rock outcrop						15
Och g							
Och h	Sequoia	Muse[e]		80	20		15
	Litz	Jefferson[e]					25
	Rock outcrop						40
Cr[f]	Maskingurn	Jefferson		90	10		60
	Lehew	Muse					25
	Hartsells						5
Єca[g]	Montevallo	Muse		85	15		60
	Litz	Jefferson					25
		Sensabaugh					
Єcb	Litz	Leadvale	Leadvale	85	15		50
	Sequoia	Muse					35
		Hamblen					
Єcc	Litz	Leadvale	Leadvale	85	15		70
	Sequoia	Hamblen					15
Єcd	Rock outcrop			90	10		75
	Litz						15
White Oak Creek Alluvium			Hamblen				
			Newark				
			Dunning				
Clinch River			Nolichucky				
			Waynesboro				

TABLE A-3 DISTRIBUTION OF SOIL SERIES OF WHITE OAK CREEK BASIN BY GEOLOGICAL UNIT AND BY SOIL CLASS

Notes:

a. Refer to Figure A-7 for soil locations.

b. Ock denotes Knox dolomite.

c. Och denotes Chickamauga limestone, whereas subsequent letters indicate various substrata (see Subsection A.3.3).

d. This group also includes portions of rock outcrop, which is restricted to soils that have more than 25 percent of their areas covered by undissolved rock.

e. These colluvial soils originated from upland Rome formation strata.

f. Cr denotes Rome formation.

g. Єc denotes Conasauga shale, whereas subsequent letters indicate various substrata (see Subsection A.3.3).

Sources:

1. W. M. McMaster and H. D. Waller, Geology and Soils of White Oak Creek Basin, Tenn. ORNL-TM-1108, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 1965.

2. R. P. Sims, State Soil Scientist, Soil Conservation Service, U.S. Department of Agriculture, letter to W. C. Abbott, Oak Ridge National Laboratory, August 1, 1974, regarding data of R. H. Moneymaker, U.S. Soil Conservation Officer, Anderson County, Tenn.

TABLE A-4 TEMPERATURE AND PRECIPITATION - OAK RIDGE AREA

Area Station X-10

Month		Climatological Standard Normals 1931 to 1960: Mean Monthly (°F)	Daily Maximum (°F)	Daily Minimum (°F)	Extremes 1945 to 1964: Highest Temperature (°F)	Lowest Temperature (°F)	Precipitation 1944 to 1964: Monthly Average[a] (in.)	Monthly Maximum (in.)	Monthly Minimum (in.)	Maximum in 24 hr (in.)
December		40.4	49.4	31.3	76	-5	5.22	10.28	1.98	4.38
January		40.1	48.9	31.2	77	-8	5.24	12.37	1.11	3.96
February		41.7	51.6	31.6	77	0	5.39	10.01	1.89	3.23
	Winter	40.7	50.0	31.4	77	-8	15.85			
March		48.0	58.9	37.0	87	4	5.44	9.69	2.05	3.84
April		58.2	70.0	46.3	89	24	4.14	8.54	1.25	2.39
May		66.9	79.0	54.8	94	32	3.42	7.01	0.90	2.09
	Spring	57.7	69.3	46.0	94	4	13.06			
June		74.7	86.1	63.3	99	41	3.38	7.55	1.18	3.08
July		77.4	88.0	66.7	103	49	5.31	10.19	2.14	3.74
August		76.5	87.4	65.6	99	44	4.02	10.31	0.50	3.31
	Summer	76.2	87.2	65.2	103	41	12.71			
September		71.1	83.0	59.2	103	33	3.59	12.84	0.21	7.75
October		60.0	72.2	47.7	91	21	2.82	6.43	0.00	2.32
November		47.8	58.6	36.5	83	4	3.49	12.00	1.01	3.20
	Fall	59.6	71.3	47.6	103	4	9.90			
	Annual	58.5	69.4	47.6	103	-8	51.52	12.84	0.00	7.75

Oak Ridge City Office

Climatological Standard Normals 1941 to 1970

Annual	57.8	68.6	47.0	105[b]	-9[b]

Knoxville Vicinity

Climatological Standard Normals 1941 to 1970

Annual	59.7	69.8	49.5	104[c]	-16[c]

TABLE A-4 TEMPERATURE AND PRECIPITATION - OAK RIDGE AREA

Notes:

a. Climatological standard normals 1931 to 1960.

b. May 1947 and October 1974.

c. January 1884 and July 1930.

Source:

Project Management Corporation and Tennessee Valley Authority, Clinch River Breeder Reactor Plant Environmental Report, vol. 1, Construction Permit Stage, Docket No. 50-537, issued April 7, 1975, Tables 2.6-4 and 2.6-8.

TABLE A-5 MONTHLY WIND DATA

	Oak Ridge City Office[a]		Knoxville Airport[b]		Area Station X-10[c]		CRBRP Meteorological Tower[d] 75 ft Level		CRBRP Meteorological Tower[d] 200 ft Level	
Month	Average Speed (mph)	Prevailing Direction	Average Speed (mph)	Prevailing Direction	Average Speed (mph))	Prevailing Direction	Average Speed (mph)	Prevailing Direction	Average Speed (mph)	Prevailing Direction
January	4.8	SW	8.2	NE	5.3	SSW	4.7	SW	8.7	SW
February	5.0	ENE	8.7	NE	6.0	SSW	7.6	WNW	8.3	SW
March	5.3	SW	9.2	NE	6.8	WSW	7.6	SW	14.3	SW
April	5.7	SW	9.3	WSW	7.0	SSW	7.6	SW	11.6	SW
May	4.5	SW	7.4	SW	6.2	NE	7.8	SW	8.4	SW
June	4.2	SW	6.7	SW	6.2	WSW	6.0	SW	8.7	SW
July	3.9	SW	6.3	WSW	4.2	SSW	7.2	SW	8.1	SW
August	3.7	E	5.7	NE	1.5	SSW	3.8	SW	4.3	SW
September	3.8	E	5.9	NE	2.9	NNE	3.1	E	3.4	ENE
October	3.6	E	5.9	NE	2.9	NNE	3.0	SW	3.6	SW
November	4.1	E	7.2	NE	3.2	N	4.7	SW	8.3	SW
December	4.5	SW	7.6	NE	4.3	NNE	4.6	WNW	6.0	ENE
Annual	4.4	SW	7.3	NE	4.7	SSW	4.9	SW	6.7	SW

Notes:

a. Sixteen-year record on wind speed, 13-year record on prevailing direction.

b. Thirty-one year record on wind speed, 14-year record on prevailing direction.

c. One-year record (102 foot, sensor elevation).

d. One-year record.

Source:

Project Management Corporation, Clinch River Breeder Reactor Plant Environmental Report, vol. 1, 179 W. Washington St., Chicago, Ill., 1975, Table 2.6-5.

TABLE A-6 WIND ROSE DATA - PERCENT OCCURRENCE OF WIND SPEED FOR ALL WIND DIRECTIONS (ORGDP WEATHER STATION, 1957 to 1969)[(a)]

Compass Point Direction	Wind Speeds (mph) 1-3	4-7	8-12	13-19	20-24	25+	Total
N	1.17%	0.75%	0.42%	0.13%	0.01%	0.0%	2.49%
NNW	0.85	0.81	0.60	0.17	0.02	0.0	2.46
NW	1.01	1.37	1.67	0.78	0.14	0.01	4.99
WNW	0.53	0.88	1.23	0.70	0.11	0.02	3.47
W	0.78	1.20	1.31	0.72	0.15	0.03	4.19
WSW	0.71	1.12	0.98	0.38	0.08	0.02	3.29
SW	1.84	3.45	3.22	1.07	0.17	0.04	9.79
SSW	1.33	1.84	1.29	0.34	0.08	0.01	4.90
S	1.84	1.97	0.97	0.28	0.05	0.02	5.13
SSE	0.58	0.40	0.12	0.04	0.01	0.0	1.15
SE	1.03	0.50	0.12	0.02	0.0	0.0	1.67
ESE	0.63	0.20	0.05	0.01	0.0	0.0	0.89
E	2.18	0.80	0.26	0.06	0.01	0.0	3.30
ENE	3.07	1.44	0.51	0.11	0.01	0.0	5.14
NE	12.07	7.24	2.05	0.54	0.05	0.0	21.96
NNE	3.90	2.12	0.66	0.16	0.01	0.0	6.85

Note:

a. Wind speed and frequency value are for wind blowing from compass point direction listed.

Source:

Air Resources Atmospheric Turbulence and Diffusion Laboratory (ATDL). Environmental Research Laboratories, "Daily, Monthly and Annual Climatological Data for Oak Ridge, Tenn., Townsite and Area Stations, January 1951 - December 1971," U.S. Department of Commerce, National Oceanic and Atmospheric Administration, ATDL Contribution File 61, July 1972.

TABLE A-7 DAILY FLOW DURATION VALUES[a] FOR WHITE OAK CREEK AND MELTON BRANCH[b]

Source	Percentage of Time Indicated Discharge Equalled or Exceeded										
	99	90	80	70	60	50	40	30	20	10	1
Melton Branch	0.10	0.22	0.35	0.50	0.69	0.92	1.30	1.80	2.80	5.00	28.00
White Oak Creek at White Oak Dam	1.90	3.30	4.40	5.30	6.20	7.30	8.70	11.00	14.00	23.00	100.00

Notes:

a. Cubic feet per second.

b. Data from Figures 11 and 12 of McMaster, 1967.

TABLE A-8 AVERAGE CONCENTRATIONS[a] OF RADIOACTIVE POLLUTANTS FOR WHITE OAK CREEK, 1970

Contaminant	EPA Std.	Sampling Station: W-1 Flume	W-2 Settling Basin	W-3 White Oak Creek (ORNL)	W-4 Melton Branch	W-5 White Oak Dam
Cl^-	250.0	14.0	34.0	21.0	41.0	11.0
F^-	1.7	1.1	1.6	0.8	1.2	0.9
NO_3^-	10.0	1.7	23.3	1.1	2.2	1.3
Phenols	0.001	0.0017	0.0013	0.0015	0.0011	0.0004
SO_4^{2-}	250.0	34.0	22.0	31.0	71.0	29.0
TDS[b]	500.0	152.0	202.0	121.0	371.0	99.0
COD[c]						7.5
Ag	0.05	<0.002	<0.002	<0.002	<0.002	<0.008
As	0.01	<0.02	<0.02	<0.02	<0.02	<0.02
Ba	1.0	0.036	0.03	0.026	0.083	0.053
Be	1.0	<0.005	<0.0005	<0.0005	<0.0005	<0.0005
Cd	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cr^{+6}	0.05	0.124	0.047	0.076	0.538	0.1
Cu	1.0	0.049	0.12	0.088	0.026	<0.032
Fe	0.3	0.04	0.1	0.09	0.02	0.17
Mn	0.05	<0.007	<0.02	<0.007	<0.008	<0.01
Se	0.01					
Zn	5.0	<0.05	<0.05	<0.05	<0.03	<0.05
Alkaline Metals		65.6	142.0	57.0	41.3	83.5
(pH)	6-9	8.3	8.7	8.2	8.2	8.0

Notes:

a. In mg/liter.

b. Total dissolved solids.

c. Chemical oxygen demand.

TABLE A-9 AVERAGE CONCENTRATIONS[a] OF NONRADIOACTIVE POLLUTANTS FOR WHITE OAK CREEK, 1971

Contaminant	EPA Std.	Sampling Station W-1 Flume	W-2 Settling Basin	W-3 White Oak Creek (ORNL)	W-4 Melton Branch	W-5 White Oak Dam
Cl^-	250.0	2.0	6.0	5.0	6.0	4.0
F^-	1.7	0.3		1.1	1.2	1.0
NO_3^-	10.0	51.8	20.5	10.3	7.2	5.3
Phenols	0.001	0.0001	0.0003	0.0002	0.0003	0.0005
SO_4^{2-}	250.0	29.0	33.0	28.0	49.0	34.0
TDS[b]	500.0	199.0	357.0	157.0	245.0	159.0
COD[c]						7.1
Ag	0.05	<0.011	0.015	<0.008	<0.008	<0.006
As	0.01	<0.053	<0.053	<0.053	<0.053	<0.053
Ba	1.0	0.036	<0.016	0.033	0.036	0.05
Be		<0.001	<0.0013	<0.001	<0.001	<0.0007
Cd	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cr	0.05	0.53	0.33	0.33	0.56	0.43
Cu	1.0	0.02	1.046	0.012	0.013	0.006
Fe	0.3	0.1	0.16	0.05	0.07	0.04
Hg	0.0002	<0.0027	<0.005	<0.0022	<0.0016	<0.0019
Mn	0.05	<0.01	0.026	<0.01	<0.01	<0.01
Pb	0.05	0.02	0.06	0.015	<0.016	<0.016
Se	0.01					
Zn	5.0	<0.07	<0.13	<0.07	0.1	<0.1
Alkaline Metals		74.9		73.6	66.2	83.7
(pH)	6-9	7.7		7.6	7.9	7.9

Notes:

a. In mg/liter.

b. Total dissolved solids.

c. Chemical oxygen demand.

TABLE A-10 CHEMICAL WATER QUALITY DATA AT WHITE OAK DAM FOR 1975 AND 1976

Substance	Standard Concentration[a] (mg/liter)	1975 Average Concentration (mg/liter)	1975 Percent Standard	1976 Average Concentration (mg/liter)	1976 Percent Standard
Cr	0.05	<0.06 ± 0.05	<120	0.02 ± 0.02	40
Zn	0.1	0.02 ± 0.03	<20	0.03 ± 0.02	30
NO_3^- (N)	10.0	0.7 ± 0.2	7	0.7 ± 0.3	7
Hg	0.005	0.0002 ± 0.0001	4	0.0002 ± 0.00005	4

Note:

a. Tennessee Stream Guidelines.

Sources:

Energy Research and Development Administration, Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1975, Y/UB 4, Union Carbide Corporation, May 1, 1976; Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976, Y/UB-6, Union Carbide Corporation, May 1, 1977.

TABLE A-11 RADIONUCLIDE CONCENTRATIONS IN CLINCH RIVER CONTRIBUTED BY WHITE OAK CREEK, 1976

Nuclide	Concentration of Radionuclides of Primary Concern (10^{-9} µCi/ml)		
	Maximum	Minimum	Average
Sr-90	2.6	0.17	1.28 ± 0.23
Cs-137	0.2	0.01	0.07 ± 0.02
Ru-106	0.08	0.01	0.04 ± 0.01
H-3	4,000.0	320.0	2,000.0 ± 317.0

Source:

Energy Research and Development Administration, Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976, Y/UB-6, Union Carbide Corporation, May 1, 1977.

TABLE A-12 URBAN CENTERS WITH POPULATION >2,500 WITHIN 80-KILOMETER (50-MILE) RADIUS FOR CENSUS YEAR 1970

Urban Center	County	Population
Knoxville	Knox	174,587
Oak Ridge	Anderson-Roane	28,319
Maryville	Blount	13,808
Athens	McMinn	11,790
Harriman	Roane	8,734
Alcoa	Blount	7,739
La Follette	Campbell	6,902
Crossville	Cumberland	5,381
Lenoir City	Loudon	5,324
Rockwood	Roane	5,259
Eagleton Village	Blount	5,345
Clinton	Anderson	4,794
Dayton	Rhea	4,361
Sweetwater	Monroe	4,340
Kingston	Roane	4,142
Etowah	McMinn	3,736
Loudon	Loudon	3,728
Oliver Springs	Anderson Morgan Roane	3,405
Sevierville	Sevier	2,661
Madisonville	Monroe	2,614
Oneida	Scott	2,602

TABLE A-13 URBAN CENTERS WITH POPULATION <2,500 WITHIN 80-KILOMETER (50-MILE) RADIUS FOR CENSUS YEAR 1970

Urban Center	County	Population
Gatlinburg	Sevier	2,329
Lake City	Anderson	1,923
Jamestown	Fentress	1,899
Englewood	McMinn	1,878
Spring City	Rhea	1,756
Pikeville	Bledsoe	1,454
Pigeon Forge	Sevier	1,361
Norris	Anderson	1,359
Luttrell	Union	819
Charleston	Bradley	792
Tellico Plains	Monroe	773
Maynardville	Union	702
Decatur	Meigs	698
Jacksboro	Campbell	689
Caryville	Campbell	648
Niota	McMinn	629
Calhoun	McMinn	624
Allardt	Fentress	610
Friendsville	Blount	575
Philadelphia	Loudon	554
Wartburg	Morgan	541
Vonore	Monroe	524
Oakdale	Morgan	376
Huntsville	Scott	337
Greenback	Loudon	318
Pleasant Hill	Cumberland	293
Townsend	Blount	267

TABLE A-14 EMPLOYEE DISTRIBUTION AMONG ERDA CONTRACTOR INSTALLATIONS, 1976

Installation		Employed	Percent
ORGDP		6,000	35
ORNL		5,200	30
Y-12		4,800	28
ERDA		927	5
ORAU		355	2
CARL		102	<1
	Total	17,384	

TABLE A-15 EMPLOYMENT LEVELS AT ORGDP, ORNL AND Y-12, 1943 TO 1976[a]

Facility	1943	1947	1952	1955	1958	1960	1963	1966	1969	1973	1974	1975	1976
ORGDP	4,900	4,900	4,900	4,230	4,952	4,150	2,700	2,570	2,750	3,000	4,300	5,000	6,000
ORNL	3,000	3,000	3,000	3,120	3,735	4,200	4,480	5,190	5,100	4,100	4,500	5,000	5,200
Y-12	3,560	3,560	3,560	3,560	6,225	5,203	5,420	4,440	5,400	6,000	5,400	5,000	4,800
Totals	11,460	11,460	11,460	10,910	14,912	13,553	12,600	12,200	13,250	13,100	14,200	15,000	16,000

Note:

a. Yearly averages.

Source:

C. R. Meyers, Jr., Spatial Distribution and Employment Trends of Manufacturing Industries in East Tennessee, 1943-1973, ORNL/NSF/EP-38, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 1974, pp. 16-17.

TABLE A-16 PAYROLL AND RESIDENCE INFORMATION, OAK RIDGE AREA (ERDA AND CPFF CONTRACTORS), DECEMBER 1975

Residence	Employees Number	Employees Percent	Payroll(b)	Payroll Percent
Total (includes all CPFF contractor employees except construction)(c)	16,007	100.0	$232,850,134	100.0
Place of Residence				
City of Oak Ridge	5,536	34.6	90,846,524	39.0
Anderson, outside Oak Ridge	2,115	13.2	27,602,356	11.9
Roane, outside Oak Ridge	2,054	12.8	26,320,368	11.3
Other locations	6,302	39.4	88,080,886	37.8
Counties				
Anderson-Roane	9,705	60.6	144,769,248	62.2
Knox	4,357	27.2	63,617,021	27.3
Loudon	868	5.4	11,164,685	4.8
Morgan	269	1.7	3,180,276	1.4
Blount	235	1.5	3,013,727	1.3
Campbell	170	1.1	2,089,220	0.9
Monroe	125	0.8	1,430,678	0.6
McMinn	51	0.3	650,874	0.3
Other	227	1.4	2,934,405	1.2
Selected Cities(d)				
Knoxville	3,424	21.4	49,331,269	21.2
Clinton	1,198	7.5	16,016,854	6.9
Kingston	965	6.2	13,217,354	5.7
Lenoir City	700	4.4	9,194,683	3.9
Harriman	638	4.0	7,721,505	3.3
Oliver Springs	592	3.7	6,846,767	2.9
Rockwood	252	1.6	3,076,001	1.3

Notes:

a. Atomic Energy Commission (AEC) was succeeded by Energy Research and Development Administration (ERDA) on January 19, 1975, CPFF - Cost plus fixed fee.

b. Employees on payroll for pay period ending December 31, 1975, or nearest to that date. Payroll data include actual annual salaries and wages paid to such employees in calendar year 1975, except in cases of new hires for which an annualized December monthly salary or wage is reported.

c. Includes ERDA - Oak Ridge Operations and Headquarters Extensions in Oak Ridge, UCC-ND, ORAU, UT-CARL and Rust (Nonmanual and manual maintenance employees).

d. Employees live in these cities or on rural postal routes served from these cities.

TABLE A-17 RESIDENCE LOCATION FOR UCC-ND EMPLOYEES, 1974

Residence	ORGDP Number	ORGDP Percent	Y-12 Number	Y-12 Percent	ORNL Number	ORNL Percent
Urban						
Oak Ridge	1,339	33.7	1,592	29.2	2,024	42.7
Clinton	284	7.2	514	9.4	221	4.7
Oliver Springs	177	4.5	229	4.2	98	2.1
Harriman	227	5.7	249	4.6	88	1.9
Kingston	377	9.5	275	5.0	233	4.9
Knoxville	671	16.9	1,221	22.4	1,113	23.5
Lenoir City	185	4.7	225	4.1	224	4.7
Rural						
Within 20 miles	267	6.7	457	8.4	360	7.6
20 to 30 miles	233	5.9	355	6.5	183	3.9
30 to 40 miles	118	3.0	193	3.5	111	2.3
40 to 50 miles	35	0.9	74	1.4	21	0.4
Over 50 miles	58	1.5	75	1.4	66	1.4
Total Outside Oak Ridge	2,632	66.3	3,867	70.8	2,718	57.3

Source:

Union Carbide Corporation, Industrial Relations Report, Nuclear Division, Oak Ridge, Tenn., 1975.

ORNL DWG 4918

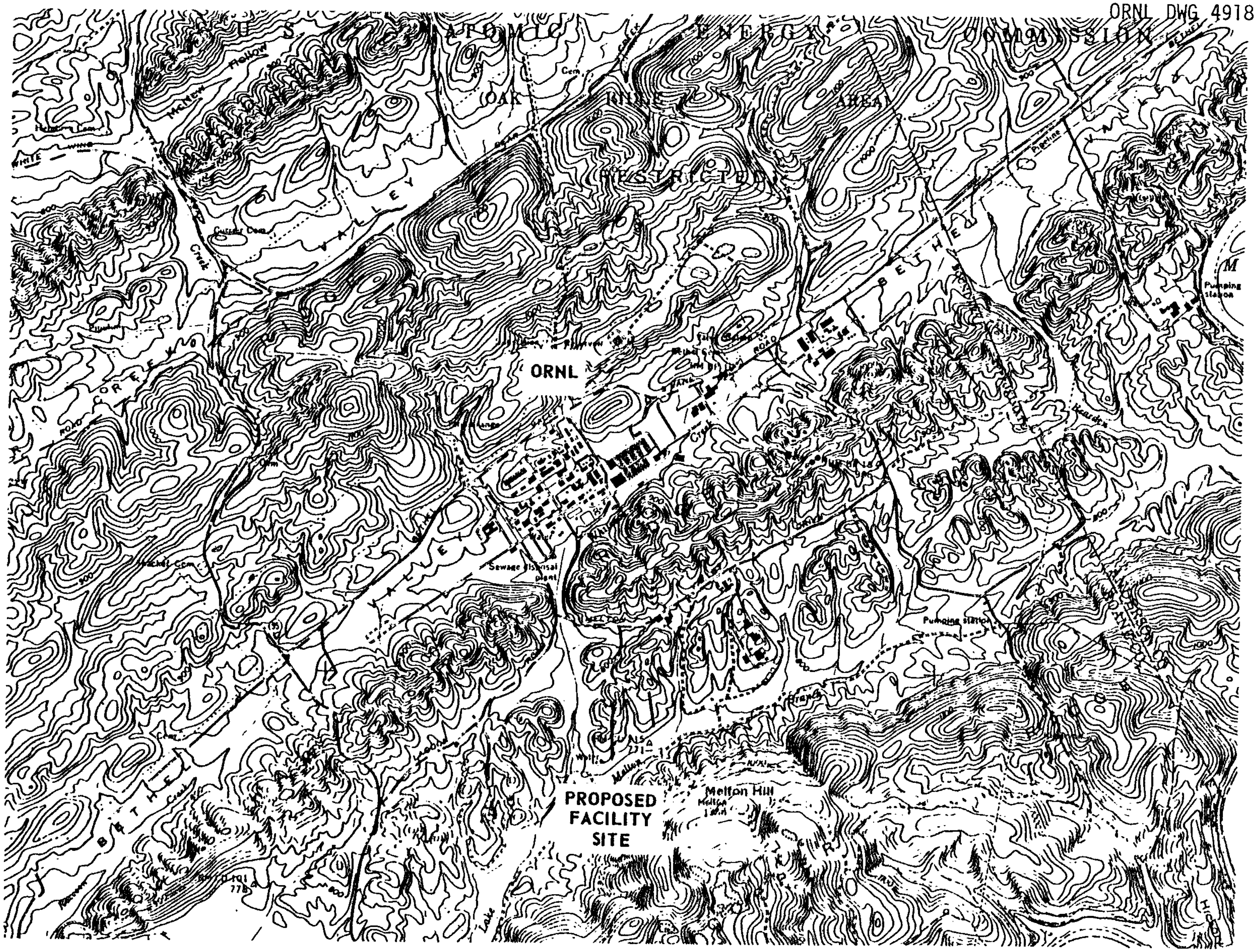
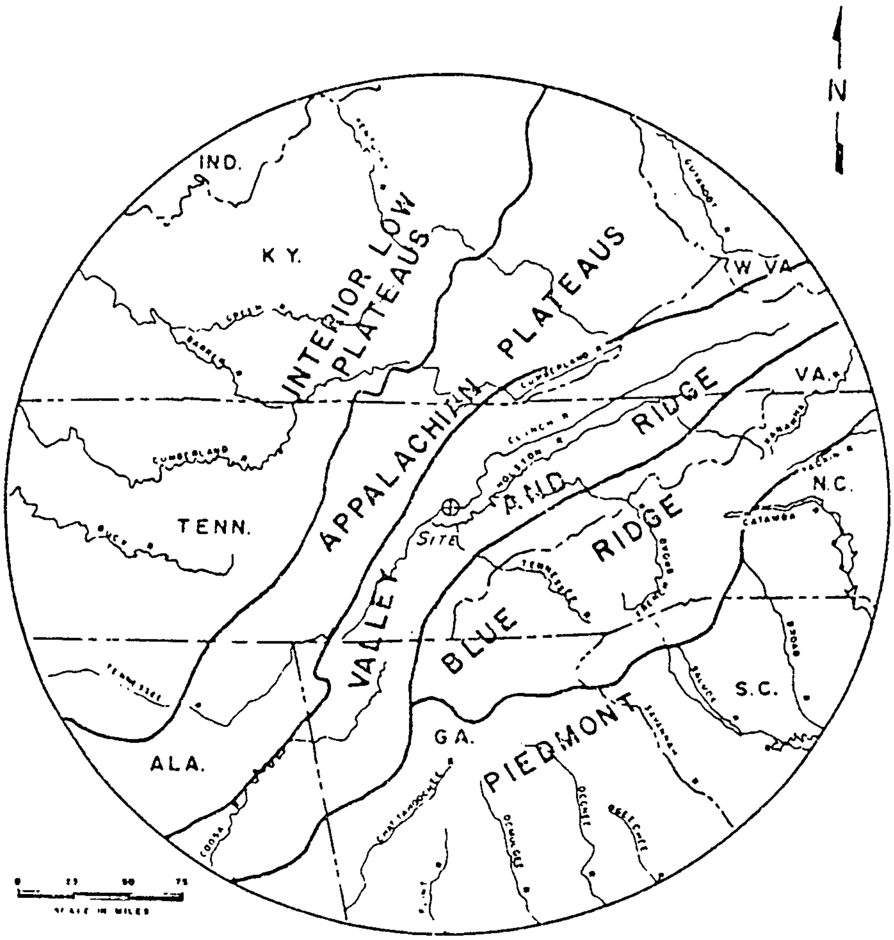


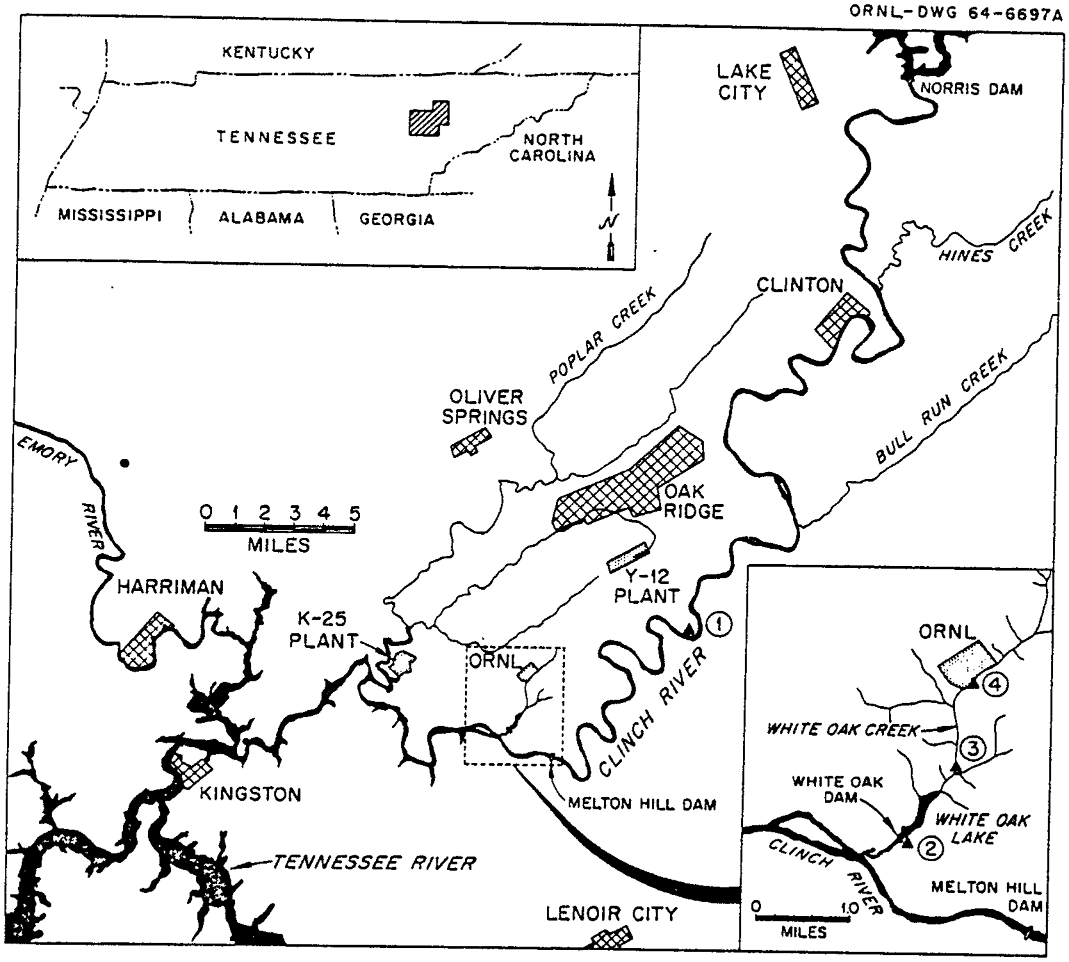
FIGURE A-1 LOCATION OF PROPOSED PROCESSING FACILITY SITE

ORNL DWG 81-4919



(FROM CRBRP-ER)

FIGURE A-2 REGIONAL PHYSIOGRAPHIC MAP OF EASTERN TENNESSEE AND SURROUNDING AREA



(FROM USAEC 1974)

FIGURE A-3 LOCATION MAP OF USERDA RESERVATION AND SURROUNDING AREA, OAK RIDGE

ORNL DWG 81-4913

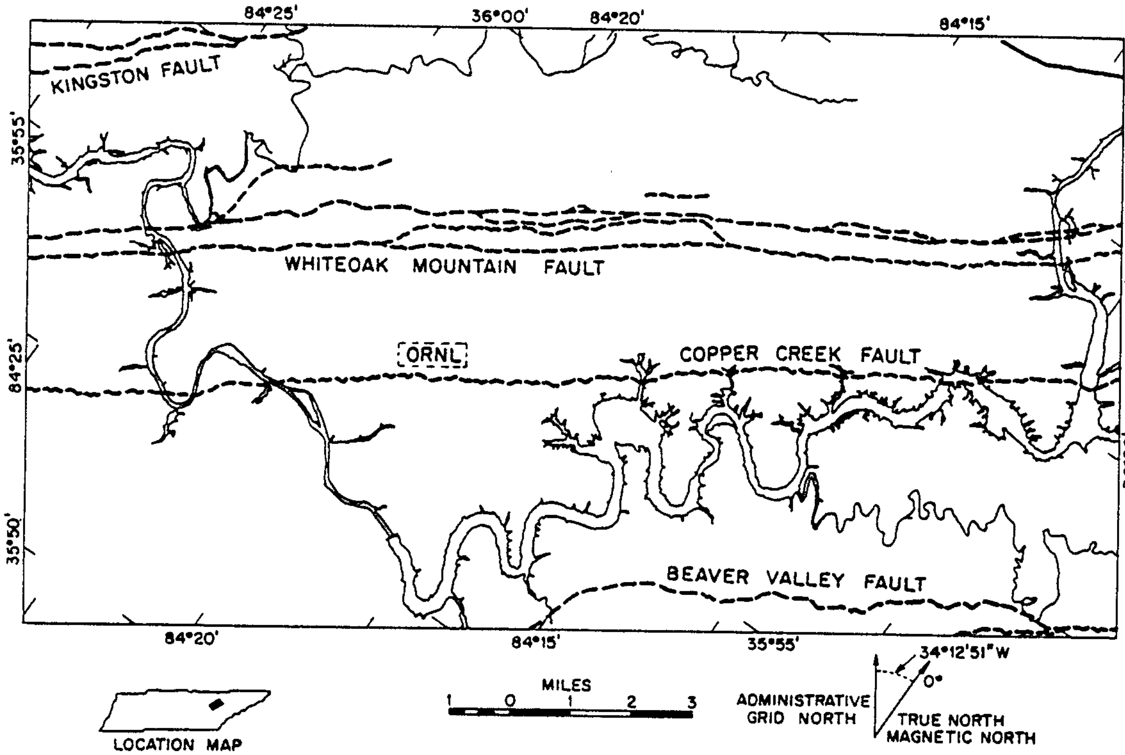


FIGURE A-4 FAULT MAP OF OAK RIDGE AREA

ORNL DWG 70-4221

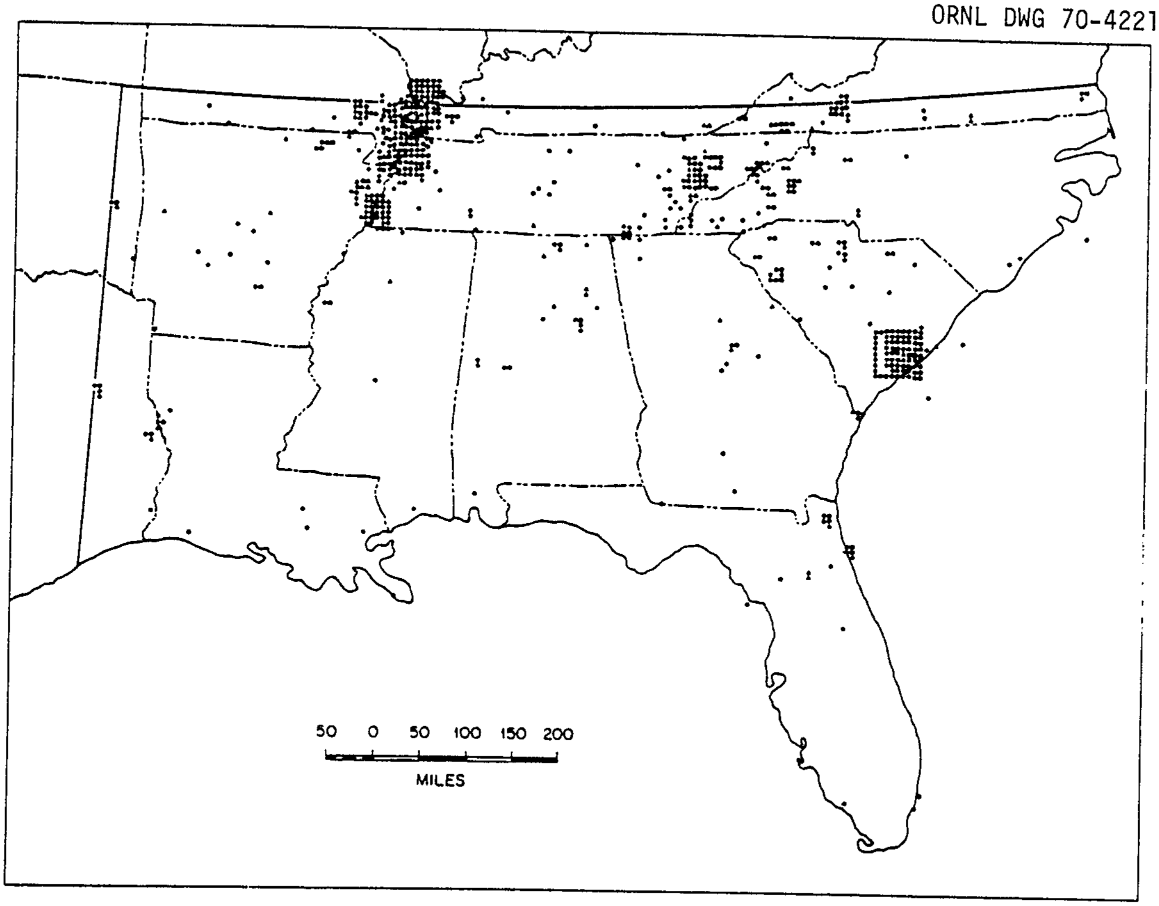


FIGURE A-5 EPICENTER LOCATIONS FOR ALL EVENTS IN SEISMIC HISTORY OF SOUTHEAST REGION

ORNL-DWG 70-4217

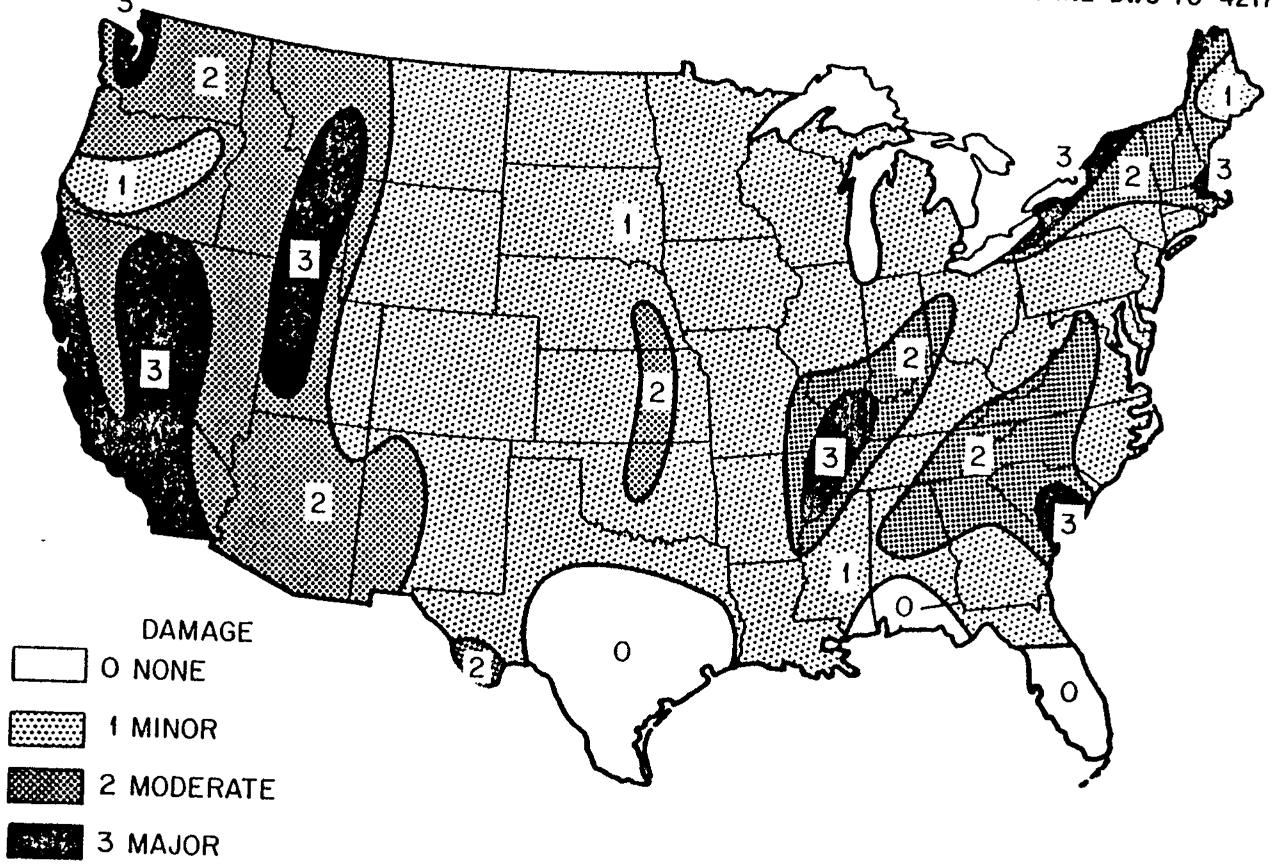


FIGURE A-6 SEISMIC RISK MAP OF UNITED STATES

ORNL DWG 81-4914

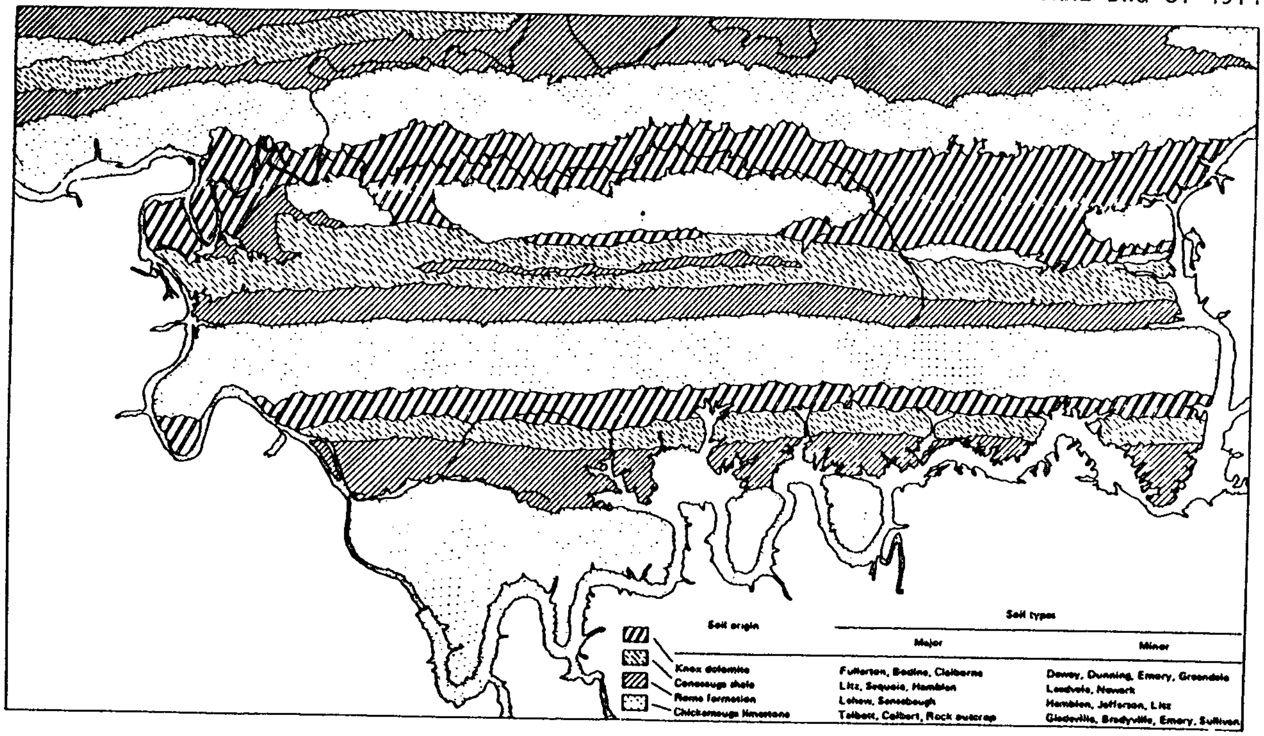


FIGURE A-7 GENERAL SOIL ASSOCIATION MAP OF OAK RIDGE RESERVATION

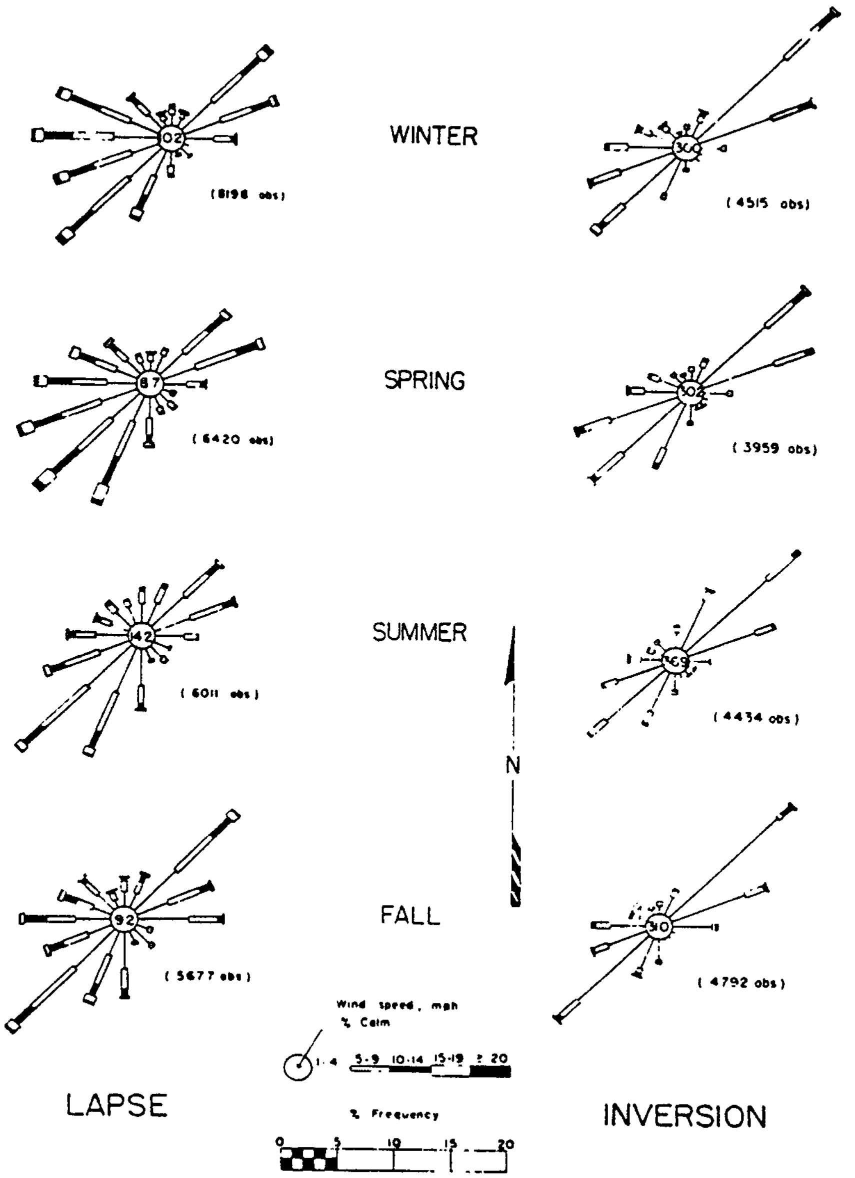
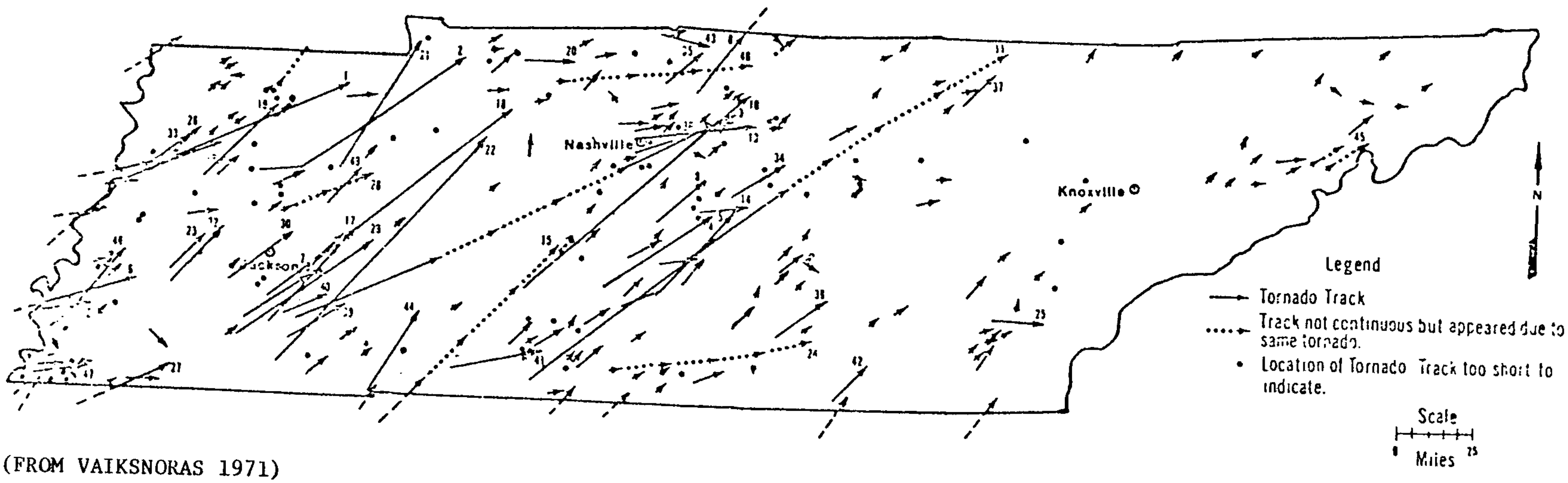


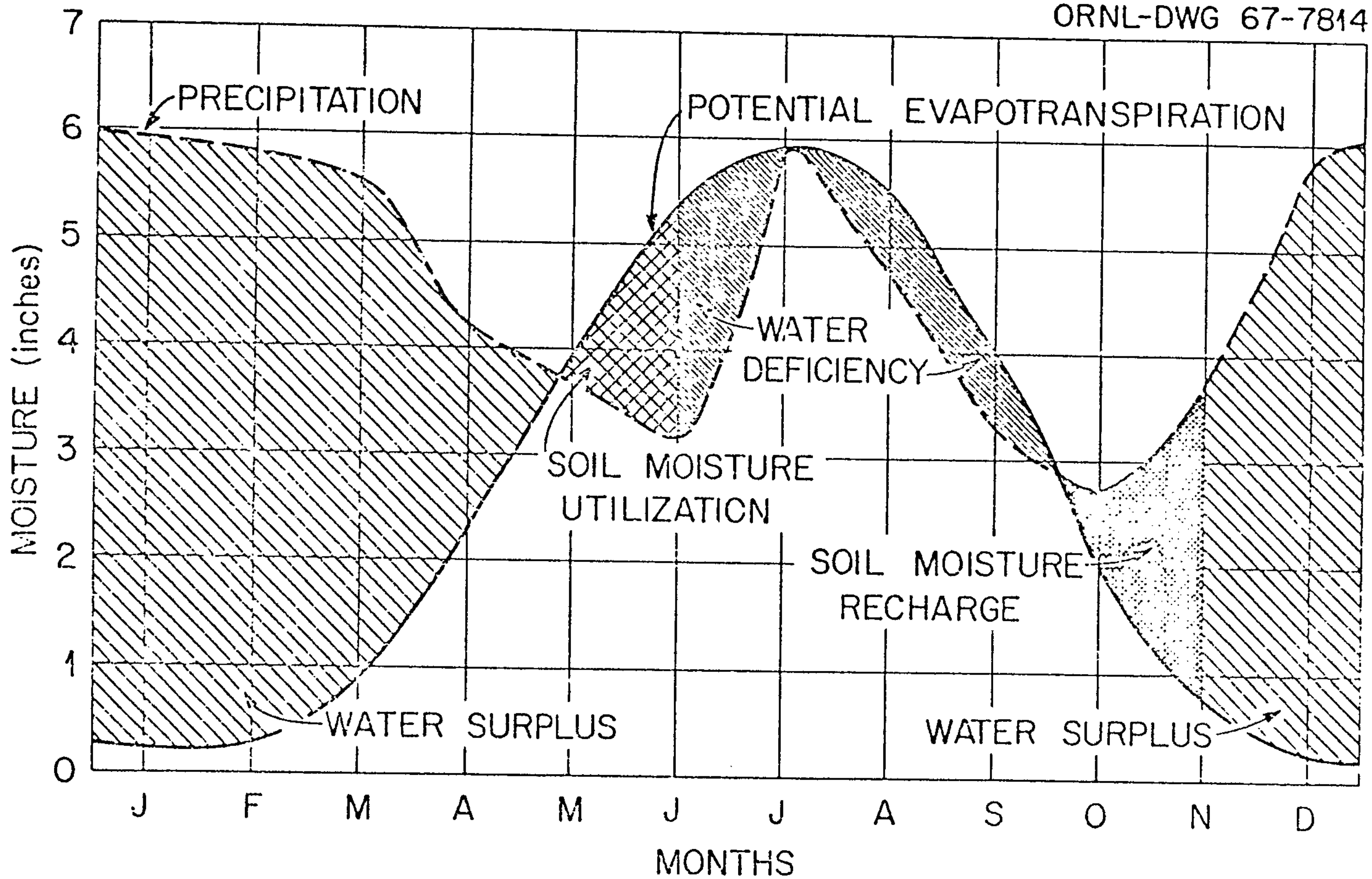
FIGURE A-8 WIND ROSE DATA, 1956 TO 1960

ORNL DWG 81-4920



(FROM VAIKSNORAS 1971)

FIGURE A-9 TRACKS OF ALL TORNADOES IN TENNESSEE FOR PERIOD 1916 TO 1970



(FROM CURLIN AND NELSON 1968)

FIGURE A-10 ANNUAL WATER BALANCE OF OAK RIDGE AREA, ASSUMING A SOIL MOISTURE STORAGE CAPACITY OF 30 CENTIMETERS (30 INCHES)

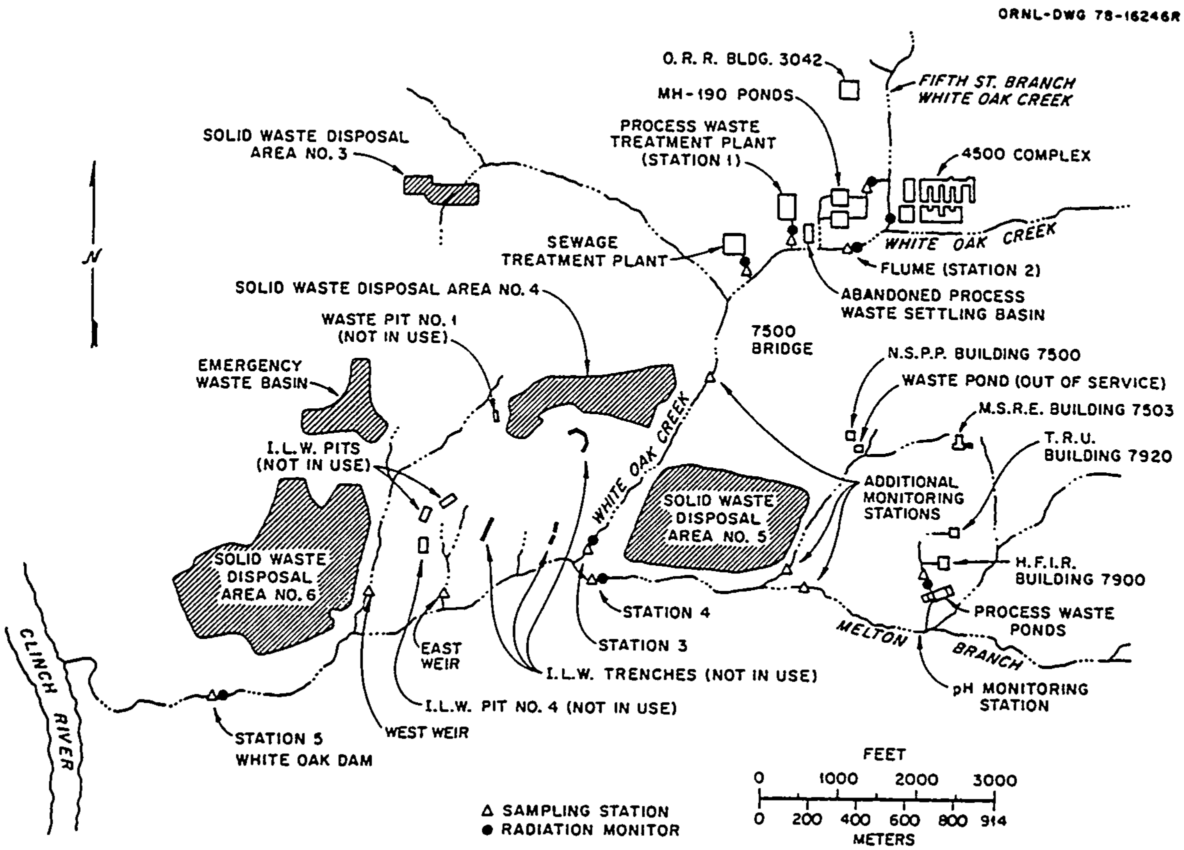


FIGURE A-11 MAP OF WHITE OAK CREEK DRAINAGE, MONITORING STATION LOCATIONS AND PRINCIPAL WASTE DISPOSAL AREAS FOR ORNL

ORNL DWG 81-4915

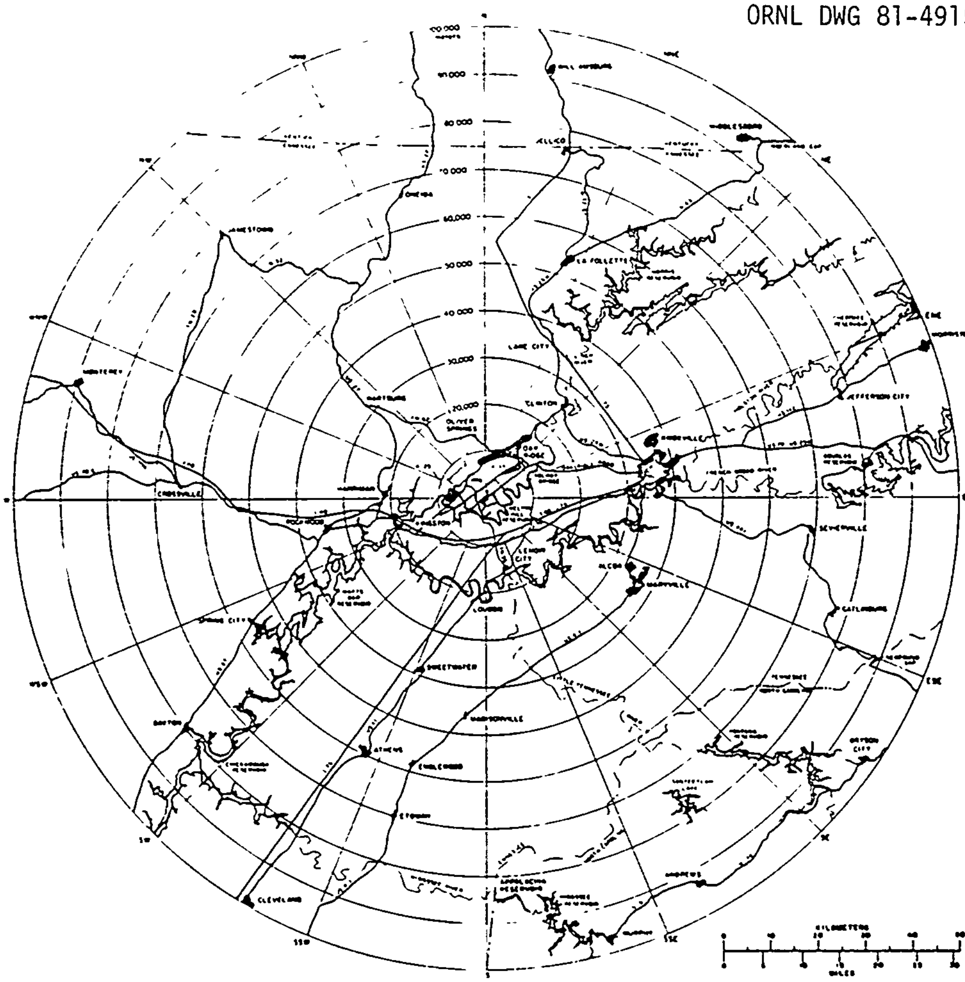


FIGURE A-12 COMMUNITIES WITH POPULATION GREATER THAN
1,500 WITHIN 100-KILOMETER (60-MILE) RADIUS

APPENDIX B

APPENDIX B

REPOSITORY WASTE ACCEPTANCE CRITERIA

Under existing Federal statutes, all repositories for disposal of high level waste must be licensed by the U.S. Nuclear Regulatory Commission (NRC). At present, a definite determination of whether the first Federal repository for TRU waste would be licensed by NRC has not been made. NRC has published "Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Waste" as part of an advanced notice of proposed rulemaking for 10 CFR 60. These criteria contain provisions regarding solidification, stabilization, free liquids, combustibles, explosives, pyrophorics, toxic materials and container design for high level waste. It is not clear at this time whether NRC TRU waste form requirements would be identical to the high level waste criteria or whether additional criteria would be adopted. If the repository is not licensed by NRC, the waste acceptance criteria would probably be determined in a manner similar to the draft waste acceptance criteria prepared for the Waste Isolation Pilot Plant (WIPP). These criteria were developed in a cooperative effort by the U.S. Department of Energy (DOE), the proposed WIPP operator and various potential WIPP users. The WIPP criteria contains provisions regarding gas generation, combustibility, immobilization, sludges, free liquid, explosives, compressed gases, pyrophoric materials, toxic materials, corrosive materials, waste container design, weight and size restrictions, surface dose rate, surface contamination, thermal power, nuclear criticality, certification, documentation, labeling and color coding.

Because of the uncertainty regarding either NRC or WIPP criteria, the study was based on assumed criteria. It should be noted that these assumptions were made in order to consider the widest range of processing options (overpacking, repackaging, compaction, etc.). The assumptions used should not be viewed as endorsement of any particular criterion or as a judgement that they would be suitable for repository operation. The assumed criteria and a discussion of how the criteria relates to ORNL's retrievable TRU waste operations follows.

Gas Generation - No restriction on gas production as a result of waste decomposition or outgassing is placed on the waste itself. It is assumed that restrictions on the total gas production in a given portion of the repository would apply to the repository operator so that the resulting pressurization would not compromise the integrity of the repository.

Combustibility - No restrictions are placed on waste combustibility. It is assumed that the hazards associated with a fire at the repository would be minimized by proper repository design, and operational and closure practices. If necessary, restrictions could be imposed on container design to provide for pressure relief to prevent overpressurization and explosion of waste containers exposed to a fire.

Immobilization - Finely divided waste material, such as ashes, are the only waste forms that are assumed to require immobilization. Based on the study guidelines presented in Section 1.0, only glass and basalt-like slag are considered suitable as immobilizing agents.

Free Liquid - Waste containers known to contain free liquid are assumed to be unacceptable at the repository. However, opening of the waste containers to verify the absence of free liquid is not included as a waste acceptance requirement.

Hazardous Materials - Hazardous materials such as explosives, compressed gases, pyrophorics, corrosive substances, etc., are assumed to be unacceptable at the repository unless it could be shown that the associated hazard is neglible. These materials are either not present in ORNL's retrievable TRU waste, stored to date, or, if present, occur in extremely small quantities. Consequently, no special provisions for these materials are included in the alternatives discussed in Subsection 4.3.

Waste Container Restrictions - No restrictions, other than those required to meet transportation requirements, are imposed on the waste containers.

Nuclear Criticality - The fissile content of individual waste containers is assumed to be acceptable if limited to 200 grams of fissile isotopes per 0.208 cubic meter (55 gallon) container, 100 grams per 0.0114 cubic meter (30 gallon) container, or 176 grams per cubic meter for larger containers. Because of the conservatism in ORNL's present criticality control procedures there should be no difficulty in complying with these limits for any of the alternatives.

Documentation - Documentation of waste properties based on existing records and/or on measurements made on the waste during processing are assumed to be acceptable to the repository operator.

APPENDIX C

APPENDIX C

DETERMINATION OF INCINERATION PROCESS FOR ALTERNATIVES EVALUATION

C.1 General

There are a large number of incineration processes, each with unique advantages and limitations for processing ORNL's TRU wastes for shipment to the Federal repository. Consequently, a preliminary review and screening of incineration processes currently in use or under development for processing radioactive wastes was required. The purpose of the review was to select an incineration process(es) to be included in the evaluation of alternatives for managing ORNL's retrievable TRU waste. The choice was based to a large extent upon engineering judgements, the advantages and limitations described in the available literature (Allen 1978; Bonner 1980; Borduin 1976; Borduin and Taboas 1980; Cox, et al. 1978; FMC 1977; GAI 1979; HEDL 1978; Kaiser 1977; Mound 1979 a, b and c; Mound 1976-8; Mound 1977-8; Oma 1979; Rockwell 1975, 1976, 1976-8, 1977-9; SRP 1979; VanDeVoorde 1977; Warren 1979; Ziegler 1974; Ziegler 1976) and limited vendor contract. If incineration is ultimately chosen as part of a method of managing ORNL's retrievable TRU waste, a detailed engineering evaluation of potential incineration processes is recommended prior to a funding request for purchase of any specific type of incinerator.

C.2 Criteria

Based on the waste characteristic described in Section 3.0 of this report, several observations affecting incinerator use can be made:

- There is a relatively large amount of noncombustibles (primarily metal objects) mixed with the combustible portion of the waste.
- A large fraction of the waste contains radionuclides that emit neutrons or high energy gamma rays.
- The waste contains enough fissile material for criticality control to be a potential concern.
- The quantity of waste to be incinerated is relatively small in comparison to the processing rates of most incinerators.

These characteristics resulted in the use of the following criteria in the review of incineration processes:

A. The process should require as little waste preparation (sorting, shredding, etc.) as possible since such operations would have to be performed remotely because of the high gamma and/or neutron levels associated with much of the waste. Any maintenance required for the waste preparation equipment might also have to be performed remotely.

B. The process must be capable of being operated in a critically safe condition.

C. The process should be such that the incinerator could be economically sized to process ORNL's retrievable TRU waste over a period of several years since construction of a facility that would process this waste in a significantly shorter period was judged to be a poor use of resources. With the waste quantities given in Section 3.0 and an assumed waste density of 300 kilograms per cubic meter, this criteria implies a processing rate of the order of tens of kilograms per hour.

D. A process in which the waste is immobilized as an integral part of the combustion process is considered more desirable than one in which immobilization of the incineration residue is performed as a separate step.

C.3 Screening of Incineration Processes

The processes considered in the review included the incinerators being developed or installed for production use at other DOE facilities, plus those processes being developed commercially that appeared to merit consideration. The processes considered are as follows:

- Acid Digestion
- Agitated Hearth
- Controlled Air
- Cyclone Drum
- Fluidized Bed
- Molten Salt
- Rotary Kiln
- Slagging (FLK Process)
- Slagging Pyrolysis
- Molten Glass

Most of these incineration processes have been recently evaluated or reviewed in several recent publications (FMC 1977, Van DeVoorde 1977, Cox, et al, 1978, Oma 1979 and Borduin and Taboas 1980). Based on these evaluations, the following six processes appeared to have more limitations and fewer advantages for the type of wastes being considered:

- Acid Digestion
- Agitated Hearth
- Cyclone Drum
- Fluidized Bed
- Molten Salt
- Slagging

These processes were deleted from further consideration for the following reasons:

Acid Digestion - With the exception of its relatively low feed rate, the acid digestion process appears to offer few advantages for the type of waste being considered. The process has a relatively low tolerance for noncombustibles and would require not only shredding of the waste but fairly extensive waste pretreatment. In addition, unless safe operation with all the potential waste constituents could be demonstrated, the process would require more extensive screening of the waste than any other process.

Agitated Hearth - This process is limited to low specific activity waste because of the large batch size required. If high specific activity waste were burned in the incinerator, the unit could contain enough fissile material that a criticality incident could be of concern.

Cyclone Drum - The cyclone drum incinerator's design simplicity and low capital cost are attractive features for the portion of ORNL's retrievable waste that is stored in drums. However, a significant fraction of the waste is stored in concrete casks. Transfer of this waste to a drum or to an incineration chamber would be required and additional preteatment may be necessary because of the nature of this water; much of it is contained in 3.8 liter (one gallon) metal containers. An additional concern is the high particulate carryover in the offgas which could cause criticality concerns in the offgas scrubbing solutions. Because of these potential problems and because the cyclone drum incinerator does not appear to be any more suitable than a controlled air incinerator for the type of waste considered, it was deleted from further consideration.

Fluidized Bed - This process requires fairly extensive waste pretreatment and has a relatively low tolerance of noncombustibles in more than tramp amounts. Both of these limitations are serious drawbacks for the type of material included in ORNL's retrievable TRU waste resulting in the deletion of this concept from consideration.

Molten Salt - The molten salt incinerator's waste pretreatment requirements and its relatively low tolerance of noncombustibles are major drawbacks for use of the process to treat ORNL's retrievable TRU waste. In the absence of a significant advantage, the molten salt incinerator was deleted.

Slagging (FLK Process) - Attractive features of the FLK process for ORNL's retrievable TRU waste include: a) the processing of both combustibles and noncombustibles; and b) immobilization of the incineration residue as part of the process. However, because of the extensive waste pretreatment requirements, the limited data available and difficulty in obtaining additional information, the FLK process was deleted from further consideration.

C.4 Determination of Processes for Alternatives Evaluation

The following incineration processes remain under consideration after the screening discussed in the previous subsection:

- Controlled Air
- Molten Glass
- Rotary Kiln
- Slagging Pyrolysis

Of these four processes, slagging pyrolysis incineration appears to be the most suitable for processing ORNL's retrievable waste. However, the smallest slagging pyrolysis incinerator presently being manufactured and marketed by ANDCO, Inc. has a processing rate over an order of magnitude higher than the rate needed to process ORNL's retrievable waste. In addition, the cost of this unit is expected to be an order of magnitude higher than the three other incinerators. For these reasons, ANDCO, Inc., was contacted to determine if a lower processing rate, less expensive unit would be feasible. ANDCO was unwilling to release any information regarding this question without performing a feasibility assessment. Since the budget and schedule for the present study could not support such an effort, the slagging pyrolysis incinerator was not considered further. It should be noted that INEL plans to investigate the feasibility of a low feed rate slagging pyrolysis incinerator but this investigation is not expected to begin until after completion of the present study (M. McCormack and J. Flinn, Private Communication, May 1980).

Of the remaining processes, the molten glass concept appears to have enough desirable characteristics for the type of waste considered to merit evaluation in the study. However, because there are many development needs that require resolution before this incinerator could be put into production use, it was decided that an additional incineration concept utilizing better developed technology should also be included in the alternatives evaluation. Either the controlled air incinerator or rotary kiln are viable candidates for this second process. The rotary kiln was selected over the controlled air unit because of its higher tolerance of noncombustibles and its automatic continuous ash removal features, both desirable for the type of material included in ORNL's retrievable waste.

A description of the molten glass and rotary kiln incineration processes and development needs are discussed below.

C.5 Description of Molten Glass Incinerator

Technology for producing high quality glasses using the conductive properties of glass at elevated temperatures is well established. However, the adaptation of electric glass-melting (electromelt) furnaces for the incineration and simultaneous fixation of resultant residues in glass is a relatively recent concept proposed for the treatment of radioactive wastes.

Penberthy Electromelt International, Inc. located in Seattle, Wash. has constructed small electromelt furnaces in which toluene, glass scraps, paper, wood, concrete, rubber, plastics and small amounts of metal have been treated. They presently are building an electromelt incinerator capable of treating up to 112 kilograms per hour of toluene of 225 kilograms per hour of cellulosic wastes.

A simplified schematic of the Penberthy process is shown in Figure C-1. Solid wastes are ram fed into the incinerator and ignite and burn above the molten glass. According to Penberthy, metals could be processed in one of the following ways: 1) the metals would be heated inductively in a sump in the incinerator until they are molten and then air would be periodically bubbled through the molten metal to oxidize it; or 2) the metal (if it occurred in sheet metal thicknesses) could be fed onto a special "shelf" in the incinerator where it would oxidize over a period of several hours and then be fed into the molten glass bath.

Ash residues along with melted and/or oxidized noncombustibles combine with the glass which is drained off periodically as excesses are generated. Depending on the waste composition, various additive compounds are fed to the electromelt bath to assure that the glass/waste matrix is chemically durable. The glass product discharges into canisters which, after cooling, are ready for transport.

Many design parameters of the molten glass incinerator are presently unavailable or are unsupported by published data. These include afterburner requirements; processing rates for both combustibles and noncombustibles (the rate of metal oxidation may be a limiting factor); dissolution rates of oxidation residues into the melt; effect of melt heterogeneity on power, temperature and melt flow distributions in the furnaces; refractory and electrode life; quality of glass matrix with widely varying feed mixtures; and the loss rate of volatile radionuclides into the offgas.

C.6 Description of Rotary Kiln Incinerator

Rotary kiln incinerators are versatile units that can be used to dispose of solid, liquid and gaseous combustible wastes. They have been utilized in both industiral and municipal installations and in special applications such as disposal of obsolete chemical warfare agents, munitions and pesticides. It is of interest to note that at least three commercial incinerator operations feed 0.208 cubic meter (55 gallon) drums into large kilns and incinerate the chemicals.

The rotary kiln is a highly efficient combustor because of its ability to attain excellent mixing of loose, unburned waste and oxygen as the kiln revolves. In addition, the rotating kiln provides a simple continuous ash removal system.

Rotary kilns can be fired directly or indirectly. Direct fired kilns are fired similar to other incinerators requiring supplemental fuel, i.e., the supplemental fuel is burned in the primary combustion chamber as required for proper combustion of the waste being incinerated. For indirect fired kilns, the fuel is fired in a furnace firebox that surrounds the rotating shell. For this reason, indirect fired kilns do not have refractory linings.

A rotary kiln has been installed at the Rocky Flats Plant for production use in processing high specific activity, plutonium contaminated waste. A simplified sketch of the unit is shown in Figure C-2. The rotary kiln was selected by Rocky Flats for high activity waste incineration because the concept provides for automatic continuous removal of ash and minimal hold-up in the unit. Both features are advantageous because low melting ash materials are processed by the unit and fissionable materials hold-up is minimized. Solid waste, supplemental fuel and combustion air are introduced at one end of the unit. Complete ash removal is accomplished by continued rotation after the feed to the unit has been stopped. Nominal waste throughput rate is 40 kilograms per hour. Normal operating temperatures are 800 degrees C in the primary combustion chamber and 1,000 degrees C in the afterburner. Startup testing of the Rocky Flats unit is now underway. Incineration of actual production wastes is scheduled for mid-1981.

The primary concerns needing resolution before using the rotary kiln for ORNL's retrievable TRU waste are the integrity and lifetime of the rotary seals that this incinerator requires and the expected lifetime of the incinerator lining.

ORNL DWG 81-4921

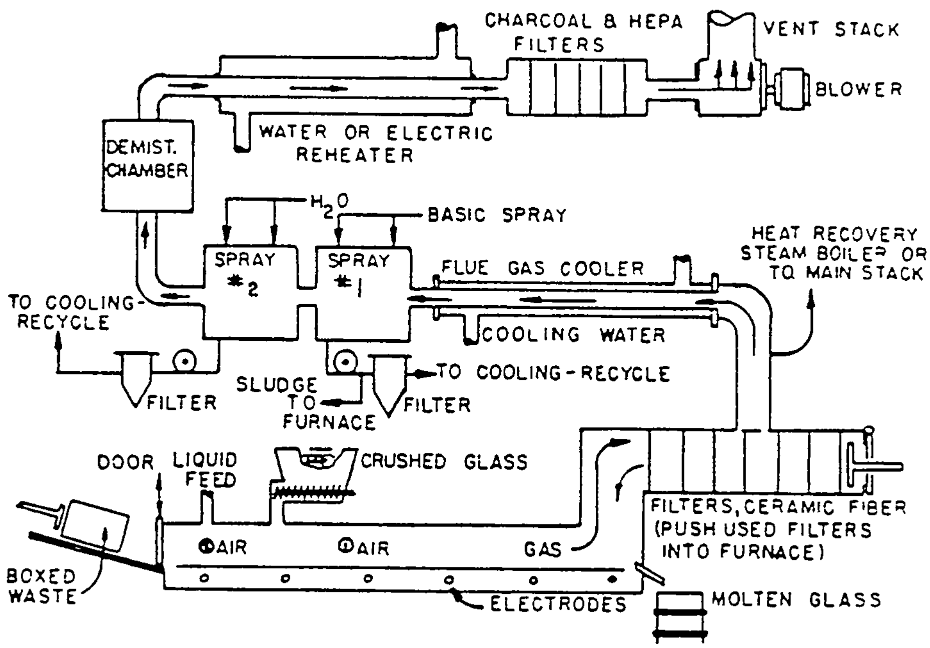


FIGURE C-1 PENBERTHY MOLTEN GLASS INCINERATOR DIAGRAM

ORNL DWG 81-4922

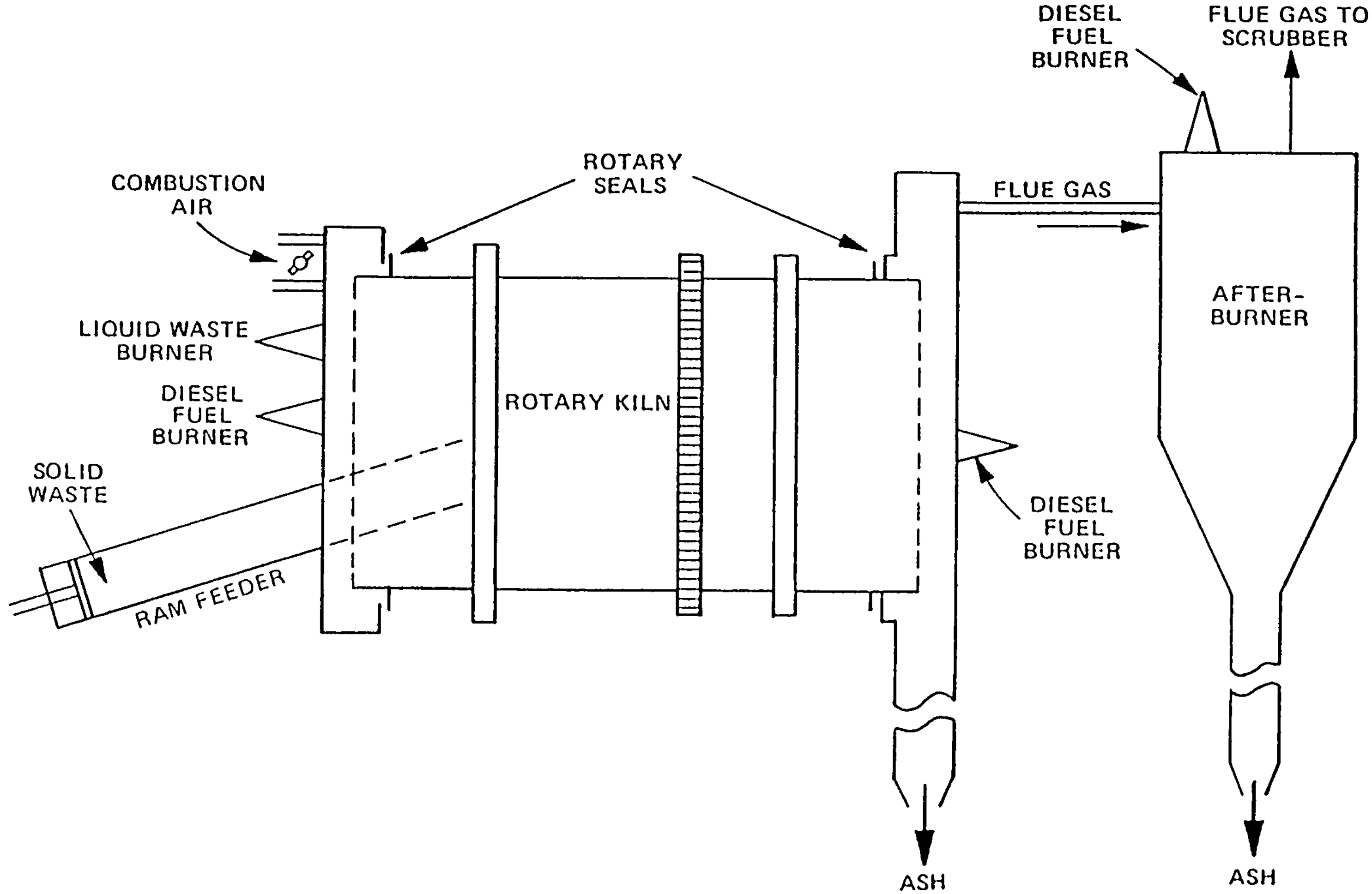


FIGURE C-2 ROTARY KILN INCINERATOR DIAGRAM

APPENDIX D

APPENDIX D

EFFECT OF PLANNED DECONTAMINATION/DECOMMISSIONING PROJECTS ON STUDY RESULTS

Decontamination and decommissioning (D&D) of a number of ORNL surplus facilities will be performed over the next 20 years. The projects currently included in the Surplus Facilities Management Program are listed in Table D-1.

Program and engineering management plans are being prepared. Studies of alternative D&D methods for specific facilities have been completed. Preliminary work plans/engineering studies are in progress for the Metal Recovery Facility, the ILW transfer line and the Curium Source Fabrication Facility. Detailed work plans for these facilities and engineering studies for other surplus facilities will be performed as resources are available.

D&D of the Molten Salt Reactor Experiment (Building 7503) and the Metal Recovery Facility (Building 3505) are the primary surplus facility projects at ORNL expected to significantly affect the TRU waste projections discussed in Section 3.0 (J. Coobs, ONRL, Private Communication, 1980). Since the planning and characterization of the D&D waste from these projects is in an early stage, it is not possible to present definitive information on how this waste will be packaged, what the waste forms will be, etc. However, the following estimated quantities and general waste characteristics of the TRU portion of these wastes have been determined as part of the initial planning for D&D of the Molten Salt Reactor Experiment and the Metal Recovery Facility:

A. Molten Salt Reactor Experiment

1. One and eighty-eight hundredths cubic meters of fuel salt and 1.98 cubic meters of flush salt (volumes at room temperature) - The fuel salt is a mixture having the composition $LiF-BeF_2-ZrF_4-UF_4$ (64.5-30.3-5.0-0.13 mole percent). The flush salt has the composition $LiF-BeF_2$ (66-34 mole percent) with about four percent by volume of fuel salt mixed into it. The fluorides in both salts evolve fluorine gas via radiolytic decomposition. Isotopic inventories in the salts as of January 1977 are given in Tables D-2 and D-3.

2. Four hundred and fifty cubic meters of U-233 contaminated material - This material consists of both equipment and structural material from the facility. The isotopic inventory for this material is not available. However, it is anticipated that many of the isotopes listed in Tables D-2 and D-3 would be present but in substantially smaller quantities. Approximately 80 percent of the contaminated material could be packaged in 0.208 cubic meter drums without difficulty. The remainder of the material could require special containers because of the bulk and/or radiation level of the material involved.

B. Metal Recovery Facility

1. Fourteen cubic meters of process equipment and piping from cells in the facility - This material could be packaged in either 0.208 cubic meter drums with shielding or in concrete casks.

2. Nine cubic meters of concrete dust and spent abrasives from decontamination of concrete in the cells - This material could be packaged in 0.208 cubic meter drums.

3. Two cubic meters of plastic and lumber from contamination barriers and cell enclosures - This material could be packaged in 0.208 cubic meter drums.

Isotopic inventories are not available for the above material. Radiation survey data for the cells is summarized in Table D-4.

The effect of the waste described in Items A and B on the evaluation of alternatives discussed in the main body of this report is dependent on the assumptions made about how the waste will be packaged and how the fuel salt will be stabilized to prevent evolution of fluorine gas. If it is assumed that the D&D waste described above is packaged and stabilized as necessary to make it compatible with the existing storage methods for retrievable TRU waste, then the main effect of this additional waste is an increase in the cost of all alternatives except Alternative 1. The additional cost for Alternative 2 is estimated to be approximately $2 million. The additional cost for the Strategy 3 alternatives is estimated to be approximately $3 million. Based on a conservative estimate of the activity present in the D&D waste, the effect on the risk assessment discussed in Section 7.0 would be minimal as would the effect on other evaluations described in the main body of this report.

Consequently, with the assumption described above, the conclusions for the various TRU waste management alternatives considered are still valid if retrievable TRU waste from D&D projects expected to be implemented prior to 1995 are included in the quantity of waste to be managed.

TABLE D-1 SURPLUS FACILITIES MANAGEMENT PROGRAM

Project	Facility Description/Location
Radiochemical Waste System	Building 3026-C
ILW Transfer Line	ILW and Hydrofracture Transfer Line
Curium Facility	Building 3028
Fission Product Development Laboratory (FPDL)	Building 3517
Waste Holding Basin	Site 3513
Metal Recovery Facility	Building 3505
Molten Salt Reactor Experiment	Building 7503
Old Hydrofracture Facility	Shale Fracturing Plant, Site 7852
Gunite Storage Tanks	W-5 to W-10, Site 3507
Waste Storage Tanks	WC-1, WC-11, WC-15, WC-17, W-1, W-2, W-3, W-4, W-13, W-14, W-15, TH-1, TH-2, TH-3, TH-4
Radioisotope Process Facility	Storage Gardens 3026-D and 3033; Carbon-14 Process System; Waste Evaporator Facility, Building 3506; Fission Product Pilot Plant, Building 3515; Shielded Transfer Tanks
Low Intensity Test Reactor	Building 3005
Homogeneous Reactor Experiment	Building 7500
ORR Experimental Facilities	ORR Water-Air Heat Exchanger, Building 3087; ORR-GCR A9-B9 Experiment Facilities; ORR-MSR Loop; ORR-Mar. Ship Loop; Pneumatic Tube Irrad. Facility; ORR-GCR Loops I and II, Building 3042
ORNL Graphite Reactor	Building 3001

TABLE D-2 RADIOACTIVITY OF HEAVY NUCLIDES IN MOLTEN SALT REACTOR EXPERIMENT SALTS

Nuclide	Activity in Curies[a]	
	Fuel Salt	Flush Salt
Tl-208[b]	58	0.4
Po-212[b]	102	0.6
Bi-212[b]	160	1.0
Pb-212[b]	160	1.0
Po-216[b]	160	1.0
Rn-220[b]	160	1.0
Ra-224[b]	160	1.0
Th-228[b]	160	1.0
U-232	156	1.0
U-233	370	2.3
U-234	19	0.1
U-235	0	0.0
U-236	0	0.0
U-238	0	0.0
Pu-238	5	0.1
Pu-239	45	0.9
Pu-240	18	0.5
Pu-241	227	4.5
Am-241	3	0.1

Notes:

a. As of January 1977

b. Activities are in secular equilibrium, decreasing with the 72 year half-life of U-232.

TABLE D-3 FISSION PRODUCT ACTIVITIES IN MOLTEN SALT REACTOR EXPERIMENT SALTS

Nuclide	Activity in Curies[a,b]
Sr-90	11,300
Y-90	11,300
Ru-106	58
Rh-106	58
Sb-125	110
Te-125m	52
Cs-137	9,500
Ba-137m	8,880
Ce-144	240
Pr-144	240
Pm-137	6,010
Sm-151	140
Eu-154	26
Eu-155	24

Notes:

a. As of January 1977

b. Total in fuel and flush salts. Long-lived fission products are distributed 98.1 percent in fuel and 1.9 percent in flush salt.

TABLE D-4 RADIATION SURVEY DATA FOR CELLS IN METAL RECOVERY FACILITY

Cell	Survey Data
A	General background, 200 mR/hr beta-gamma. Alpha probes on floor and walls showed from 30,000 disintegrations per minute (d/m), with one spot near exit door which probes 240,000 d/m per 100 cm^2 alpha and 300 mR/hr per 100 cm^2 beta-gamma.
B	General background, 20-50 mR/hr beta-gamma. Floor probes more than 300,000 d/m alpha.
C	General background, less than 10 mR/hr beta-gamma. Alpha probes 10,000 d/m per 100 cm^2 center floor, 25,000 d/m northeast floor and 2,500 d/m near south floor. Smears on northwest floor are 3,000 d/m alpha, south center floor 750 d/m alpha, northeast floor 4,000 d/m alpha, brick barricade 500 d/m alpha and ladder less than 500 d/m alpha.
E	General background, less than 10 mR/hr beta-gamma. Alpha probe more than 500,000 d/m at north door ledge, 300,000 d/m on wall above north door and 30,000 d/m on tank at north door. General probe on floor 2,500 d/m alpha, with spots up to 25,000 d/m alpha. Equipment smears 500 d/m alpha. Floor at south door and floor on south side near pit both smear 1,200 d/m alpha.
F	General background, less than 10 mR/hr beta-gamma. Alpha probes were 40,000 d/m on north door ledge, 5,000 d/m on top of tank, 15,000 d/m in center of floor, with a spot in northwest center floor over 500,000 d/m. Smears were 5,000 d/m alpha on door ledge, 500 d/m alpha, 750 d/m alpha on small tank, 5,000 d/m alpha at door on south side floor, 1,000 d/m on east, west and south walls, 5,000 d/m alpha on barrels, pipe and medium-size tank and 7,000 d/m alpha at center of floor at drain.
G	General background, less than 10 mR/hr beta-gamma. Alpha probes in this cell were all greater than 500,000 d/m. Smears were 5,000 d/m alpha, 25,000 d/m on pipes, 40,000 on north door and pipe, 75,000 d/m alpha on columns and 25,000 d/m on floor in front of south door.

APPENDIX E

APPENDIX E

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